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U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

2018 Annual Merit Review Vehicle Technologies Office

Results Report

November 2018

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Introduction

The 2018 U.S. Department of Energy (DOE) Vehicle Technologies Office (VTO) Annual Merit Review (AMR) was held June 18-21, 2018, in Arlington, Virginia. The review encompassed work done by VTO: 235 individual activities were reviewed by 247 reviewers. Exactly 1,202 individual review responses were received for the VTO technical reviews.

The objective of the meeting was to review VTO accomplishments over the previous 12 months and provide an opportunity for industry, government, and academia to give inputs to DOE with a structured and formal methodology. The meeting also provided attendees with a forum for interaction and technology information transfer.

The peer review process followed the guidelines of the Peer Review Guide developed by the Office of Energy Efficiency and Renewable Energy (EERE). Each activity is reviewed every 3 years, at a minimum. However, VTO strives to have every activity reviewed every other year. The reviewers for the technical sessions were drawn from a wide variety of backgrounds, including current and former vehicle industry members, academia, government, and other expertise areas. Each reviewer was screened for conflicts of interest as prescribed by the Peer Review Guide. A complete list of the meeting participants is presented as Appendix A.

Evaluation Criteria—Research & Development Subprogram Projects

In the technical research and development (R&D) subprogram sessions, reviewers were asked to respond to a series of specific questions regarding the breadth, depth, and appropriateness of the VTO R&D activities. The technical questions are listed below, along with appropriate scoring metrics. These questions were used for all formal VTO R&D project reviews.

Question 1. Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned. (Scoring weight for overall average = 20%)

- 4.0=Outstanding (sharply focused on critical barriers; difficult to improve approach significantly)
- 3.5=Excellent (effective; contributes to overcoming most barriers)
- 3.0=Good (generally effective but could be improved; contributes to overcoming some barriers)
- 2.5=Satisfactory (has some weaknesses; contributes to overcoming some barriers)
- 2.0=Fair (has significant weaknesses; may have some impact on overcoming barriers)
- 1.5=Poor (minimally responsive to project objectives; unlikely to contribute to overcoming the barriers)
- 1.0=Unsatisfactory (not responsive to project objectives; unlikely to contribute to overcoming the barriers).

Question 2. Technical accomplishments and Progress toward overall project and DOE goals—the degree to which progress has been made and plan is on schedule. (Scoring weight for overall average = 40%)

- 4.0=Outstanding (sharply focused on critical barriers; difficult to improve significantly)
- 3.5=Excellent (effective; contributes to overcoming most barriers)
- 3.0=Good (generally effective but could be improved; contributes to overcoming some barriers)
- 2.5=Satisfactory (has some weaknesses; contributes to overcoming some barriers)
- 2.0=Fair (has significant weaknesses; may have some impact on overcoming barriers)
- 1.5=Poor (minimally responsive to project objectives; unlikely to contribute to overcoming the barriers)
- 1.0=Unsatisfactory (not responsive to project objectives; unlikely to contribute to overcoming the barriers).

Question 3. Collaboration and Coordination Across Project Team. (Scoring weight for overall average = 10%)

- 4.0=Outstanding (close, appropriate collaboration with other institutions; partners are full participants and well-coordinated)
- 3.5=Excellent (good collaboration; partners participate and are well-coordinated)
- 3.0=Good (collaboration exists; partners are fairly well-coordinated)
- 2.5=Satisfactory (some collaboration exists; coordination between partners could be significantly improved)
- 2.0=Fair (a little collaboration exists; coordination between partners could be significantly improved)
- 1.5=Poor (most work is done at the sponsoring organization with little outside collaboration; little or no apparent coordination with partners)
- 1.0=Unsatisfactory (no apparent coordination with partners).

Question 4. Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please select N/A. (Scoring weight for overall average = 10%)

- 4.0=Outstanding (sharply focused on critical barriers; difficult to improve significantly)
- 3.5=Excellent (effective; contributes to overcoming most barriers)
- 3.0=Good (generally effective but could be improved; contributes to overcoming some barriers)

- 2.5=Satisfactory (has some weaknesses; contributes to overcoming some barriers)
- 2.0=Fair (has significant weaknesses; may have some impact on overcoming barriers)
- 1.5=Poor (minimally responsive to project objectives; unlikely to contribute to overcoming the barriers)
- 1.0=Unsatisfactory (not responsive to project objectives; unlikely to contribute to overcoming the barriers)
- N/A=Not Applicable (project has ended).

Question 5. Relevance—Does this project support the overall DOE objectives? (Scoring weight, not included with overall average = 20%)

- Yes
- No.

Question 6. Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

- Excessive
- Sufficient
- Insufficient.

Evaluation Criteria—Technology Integration Projects

Reviewers for the Technology Integration (TI) technical session answered questions tailored to TI's 2018 AMR focus on increasing transportation efficiency and fuel diversity. These technical questions are listed below, along with appropriate scoring metrics.

Question 1. Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency. (Scoring weight for Project Objectives = 20%)

- 4.0=Outstanding (project objectives are sharply focused on supporting DOE/VTO objectives increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency. The project has a direct and substantial impact upon addressing barriers; difficult to improve project objectives significantly)
- 3.5=Excellent (project objectives are effective; project addresses a significant number of barriers; effectively contributes to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency)
- 3.0=Good (project objectives are generally effective, but could be improved; project addresses some barriers; contributes to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency)

- 2.5=Satisfactory (project objectives have some weaknesses; project addresses some barriers; project may have some impact contributing to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency)

- 2.0=Fair (project objectives have significant weaknesses; project addresses few barriers; project may have a small impact contributing to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency)

- 1.5=Poor (project objectives are minimally responsive to DOE/VTO objectives; project does not address barriers; project is unlikely to contribute to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency)

- 1.0=Unsatisfactory (project objectives are not responsive to DOE/VTO objectives; project fails to address any barriers; project is highly unlikely to contribute to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency).

Question 2. Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts. (**Scoring weight for Project Approach = 20%**)

- 4.0=Outstanding (project approach is sharply focused on achieving project objectives; difficult to improve project approach significantly)

- 3.5=Excellent (effective; project approach contributes to achieving the majority of project objectives)

- 3.0-Good (generally effective but project approach could be improved; contributes to achieving some of the project objectives)

- 2.5=Satisfactory (has some weaknesses; project approach contributes to achieving some project objectives)

- 2.0=Fair (has significant weaknesses; project approach may have some impact on achieving project objectives)

- 1.5=Poor (minimally responsive to project objectives; project approach is unlikely to contribute to achieving project objectives)

- 1.0=Unsatisfactory (not responsive to project objectives; project approach is highly unlikely to contribute to achieving project objectives).

Question 3. Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals. (**Scoring weight for Project Accomplishments = 40%**)

- 4.0=Outstanding (project demonstrates significant accomplishments; strong progress toward achieving both project and DOE objectives; difficult to improve progress significantly)

- 3.5=Excellent (project demonstrates many accomplishments; very effective progress toward achieving overall project objectives and DOE goals)

- 3.0=Good (project accomplishments are generally effective; progress is on schedule to contribute to some project objectives and DOE goals)

- 2.5=Satisfactory (project has some accomplishments, but also displays some weaknesses; progress could be improved; contributes to some project objectives and DOE goals)

- 2.0=Fair (project has few accomplishments and demonstrates significant weaknesses; rate of progress is slow; minimal contribution to project objectives or DOE goals)

- 1.5=Poor (minimal demonstration of accomplishments; progress is significantly behind schedule; unlikely to contribute to project objectives or DOE goals)

- 1.0=Unsatisfactory (project demonstrates no accomplishments; limited or no demonstrated progress; not responsive to project objectives).

Question 4. Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners. (Scoring weight for Collaboration and Coordination = 10%)

- 4.0=Outstanding (sharply focused on collaboration among project team members; team is well-suited to effectively carry out the work of the project and have strong working relationships; no notable weaknesses)

- 3.5=Excellent (effective; team members meaningfully contribute to carrying out the work of the project, are well-suited to perform the work and have excellent working relationships)

- 3.0=Good (generally effective but could be improved; collaboration exists; team members are fairly well-suited to project work and have good working relationships)

- 2.5=Satisfactory (has some weaknesses; collaboration among team members is satisfactory for carrying out the work of the project; project partnerships, team members and working relationships could be improved)

- 2.0=Fair (has significant weaknesses; little collaboration exists and team could be improved)

- 1.5=Poor (minimally responsive; little collaboration exists and team lacks effective working relationships)

- 1.0=Unsatisfactory (little or no apparent collaboration between team members; project team is lacking critical expertise to effectively carry out the work of the project).

Question 5. Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency. (Scoring Weight for Overall Impact=10%).

- 4.0=Outstanding (sharply focused on critical barriers to achieving project objectives; difficult to improve significantly)

- 3.5=Excellent (effective; contributes to overcoming most barriers to achieving project objectives)

- 3.0=Good (generally effective in overcoming barriers to achieving project objectives)
- 2.5=Satisfactory (has some weaknesses; but needs better focus on overcoming some barriers to achieve project objectives)
- 2.0=Fair (has significant weaknesses)
- 1.5=Poor (minimally responsive)
- 1.0=Unsatisfactory (not responsive to eliminating barriers to achieving project objectives).

Question 6. Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

- Yes
- Maybe
- No.

Project Scoring

R&D Subprogram Projects

For R&D subprogram sessions, reviewers were asked to provide numeric scores (on a scale of 1.0-4.0 in one-half point increments, as indicated above) for Question 1 through Question 4 of each formally reviewed activity. For each reviewed project, the individual reviewer scores for Question 1 through Question 4 were averaged to provide information on the project's question-by-question scoring. Scores for each of these four criteria were weighted using the formula below to create a Weighted Average for each project. This allows a project's question-by-question and final overall scores to be meaningfully compared against another project:

Weighted Average = [Question 1 Score x 0.20] + [Question 2 Score x 0.40] +

[Question 3 Score x 0.10] + [Question 4 Score x 0.10]

Each reviewed activity has a corresponding bar chart representing that project's average scores for each of the four designated criteria. As demonstrated in Figure 1, a bullet and error line are included within the green bars representing the corresponding average and standard deviation of criteria scores for all of the reviewed projects in the same subprogram.

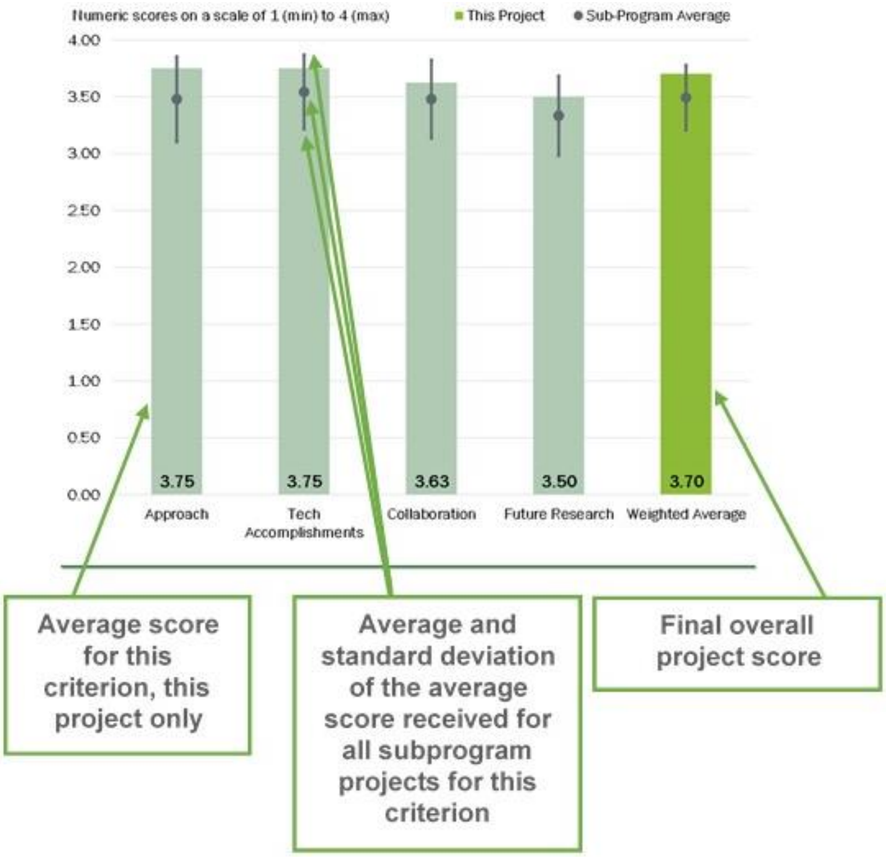

Figure 1. Sample Question 1 through Question 4 score averages, standard deviations, and overall Weighted Average for an R&D project.

Reviewers were also asked to evaluate a given project's relevance and funding through Question 5 and Question 6, which were each scored on a different scale than Question 1 through Question 4. For the R&D subprogram sessions, while Question 1 through Question 4 were rated on a 1.0 to 4.0 scale in one-half point increments, Question 5 was rated on a yes or no scale, and Question 6 was rated on an excessive, sufficient, or insufficient scale. Consequently, Question 5 and Question 6 results were excluded from the Weighted Average calculation because the scoring scales are incompatible. As demonstrated in Figure 2, each reviewed activity has pie charts representing that project's population distributions for each reviewer rating associated with Question 5 and Question 6.

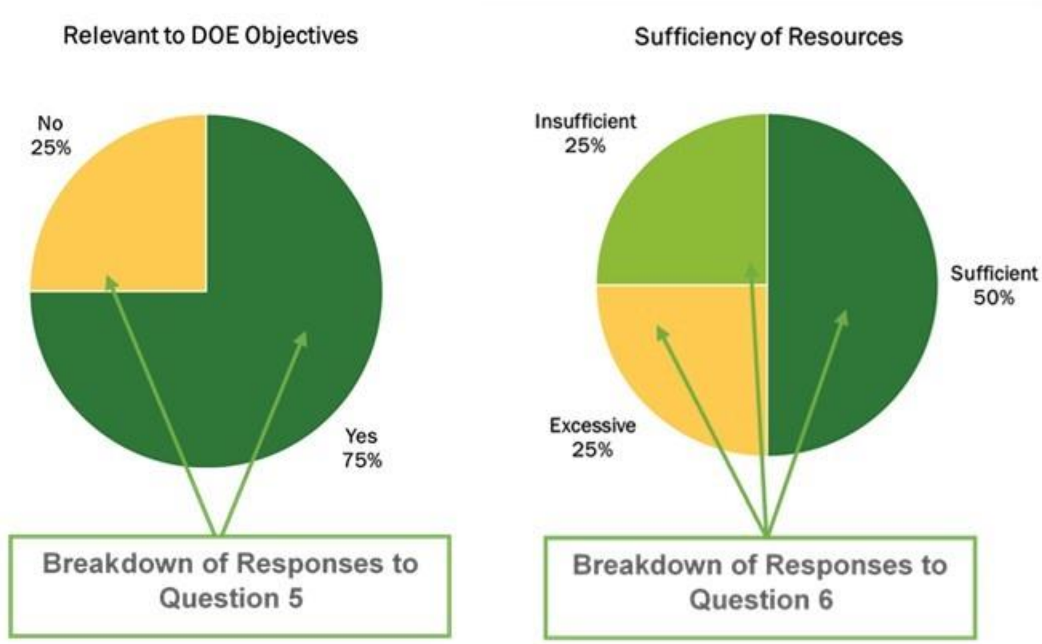

Figure 2. Sample Question 5 and Question 6 population distribution for R&D subprogram project.

TI Subprogram Projects

For the TI subprogram session, reviewers were asked to provide numeric scores (on a scale of 1.0-4.0 in one-half point increments, as indicated above) for Question 1 through Question 5 of each formally reviewed activity. For each reviewed project, the individual reviewer scores for Question 1 through Question 5 were averaged to provide information on the project's question-by-question scoring. Scores for each of these five criteria were weighted using the formula below to create a Weighted Average for each project. This allows a project's question-by-question and final overall scores to be meaningfully compared against another project:

Weighted Average = [Question 1 Score x 0.20] + [Question 2 Score x 0.20] +

[Question 3 Score x 0.40] + [Question 4 Score x 0.10] + [Question 5 Score x 0.10]

Each reviewed TI activity has a corresponding bar chart representing that project's average scores for each of the five designated criteria. As demonstrated in Figure 3, a bullet and error line are included within the green bars representing the corresponding average and standard deviation of criteria scores for all of the reviewed projects in the same subprogram.

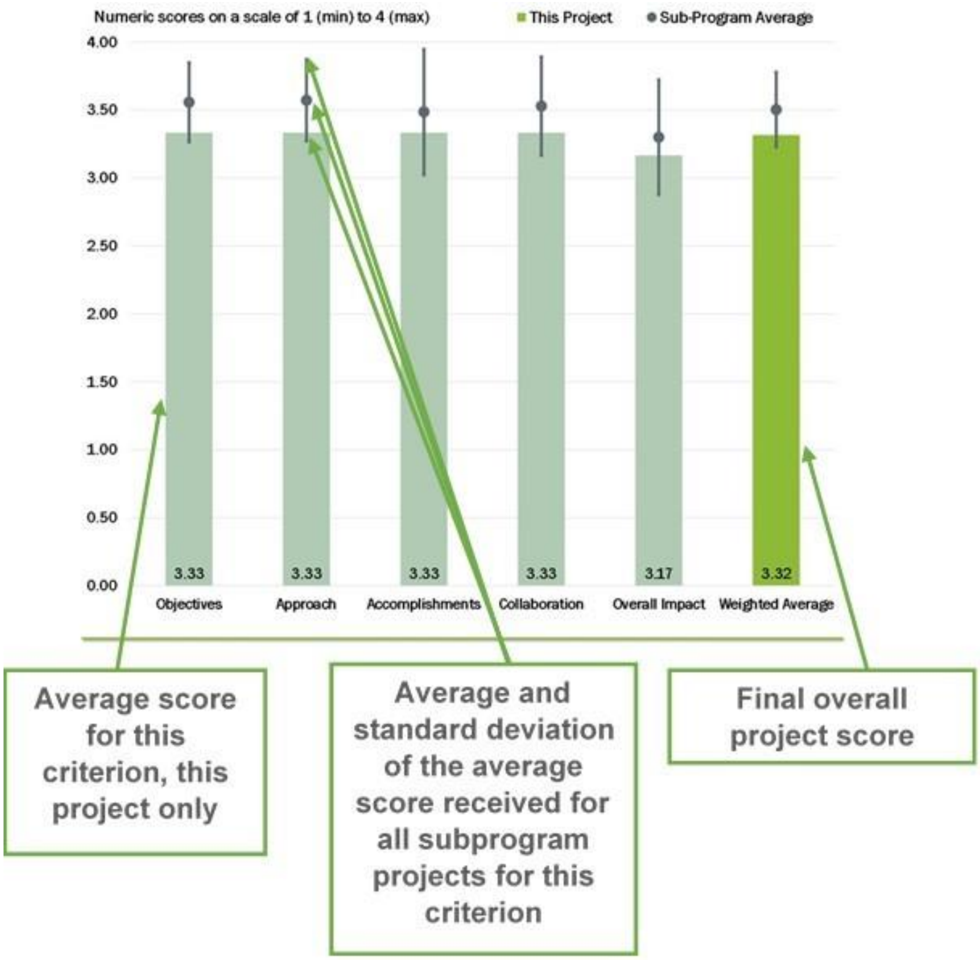

Figure 3. Sample Question 1 through Question 5 score averages, standard deviations, and overall Weighted Average for a TI subprogram project.

For TI projects, Question 1 through Question 5 were rated on a 1.0 to 4.0 scale in one-half point increments, whereas Question 6 was rated on a yes, maybe, or no scale. Consequently, Question 6 results were excluded from the Weighted Average calculation because the scoring scales are incompatible. As demonstrated in Figure 4, similar to the R&D subprograms, each reviewed activity for TI projects has a pie chart representing that project's population distributions for each reviewer rating associated with Question 6.

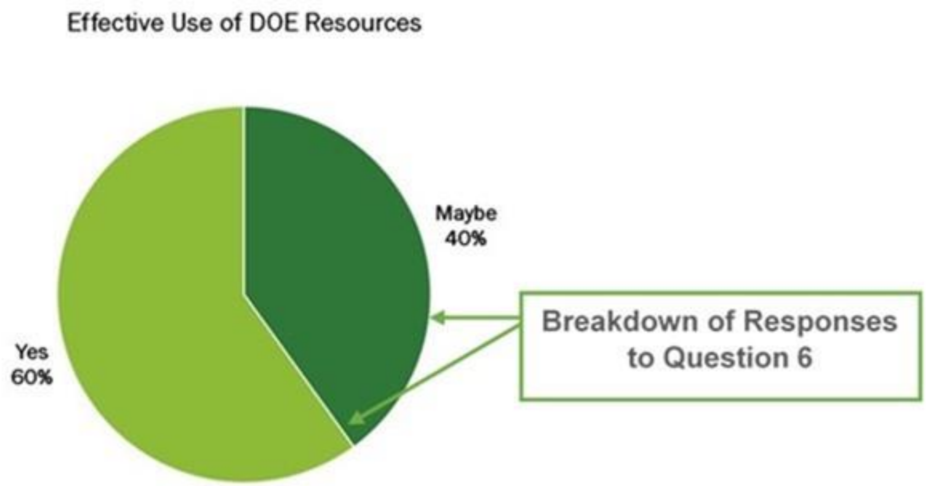

Figure 4. Sample Question 6 population distributions for TI resources question.

Reviewer Responses

Text responses and numeric scores to the questions were submitted electronically through a web-based software application, PeerNet, operated by Oak Ridge Associated Universities (ORAU). Database outputs from this software application were analyzed and summarized to collate the multiple-choice, text comments, and numeric scoring responses and produce the summary report.

Responses to the questions are summarized in this report, with summaries of numeric scores for each technical session, as well as text and graphical summaries of the responses for each individual technical activity. For each project, the reviewer sample size is identified.

Each reviewed activity is identified by Presentation Number, followed by the Presentation Title, the Principal Investigator (PI), and the PI's organization. For each subprogram area, reviewed activities are ordered numerically by project number. Figure 5, below, provides an example project title.

Presentation Number: acs002 Presentation Title: Light-Duty Diesel Combustion
Principal Investigator: Stephen Busch (Sandia National Laboratories)

Figure 5. Sample project title with presentation ID, presentation title, PI, and PI organization.

For each project, in addition to the PI, the presenter at the AMR is identified, along with the reviewer sample size. For some projects, the presenter at the AMR was a project team member rather than the PI.

Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc.

Note that for each question the order of reviewer comments may be different; for example, for each specific project the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc. Not all reviewers provided a response to each question for a given project.

The report is organized by technical subprogram area. Each technical area section includes a summary of that subprogram, reviewer feedback received specific to the subprogram overview presentation(s) given by DOE, a subprogram activities score summary table (and page numbers), and project-specific reviewer evaluation comments with corresponding bar and pie charts.

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1. Advanced Combustion Systems

To strengthen national security, enable future economic growth, support energy dominance, and increase transportation energy affordability for Americans, the Vehicle Technologies Office (VTO) funds early-stage, high-risk research. The research will generate knowledge that industry can advance to deploy innovative energy technologies to support affordable, secure, reliable and efficient transportation systems across America. VTO leverages the unique capabilities and world-class expertise of the national laboratory system and works with partners across industry and academia to develop new innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures and better powertrains; and energy efficient mobility technologies and systems, including connected and automated vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement. VTO is uniquely positioned to address early-stage challenges due to its strategic research partnerships with industry (e.g., the U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise. These partnerships prevent duplication of effort, focus U.S. Department of Energy (DOE) research on the most critical research and development (R&D) barriers, and accelerate progress. VTO focuses on research that industry either does not have the technical capability to undertake on its own— usually because there is a high degree of scientific or technical uncertainty—or it is too far from market realization to merit sufficient industry emphasis and resources.

The Advanced Combustion Systems (ACS) subprogram supports early-stage R&D to improve our understanding and ability to manipulate combustion processes, fuel properties, and catalyst formulations. This generates the knowledge and insight necessary for industry to develop the next-generation of engines and fuels for light-duty (LD) and heavy-duty (HD) vehicles. As a result, co-optimization of higher-efficiency engines and high performance fuels has the potential to improve LD fuel economy by 35% (25% from advanced engine research and 10% from co-optimization with fuels) by 2030 compared to 2015 gasoline vehicles. The subprogram supports cutting-edge research at the national laboratories, in close collaboration with academia and industry, to strengthen the knowledge base of high-efficiency, advanced combustion engines, fuels, and emission control catalysts. The ACS subprogram utilizes unique facilities and capabilities at the national laboratories to create knowledge, new concepts and research tools that industry can use to develop advanced combustion engines and co-optimize with fuels that will provide further efficiency improvements and emission reductions. These unique facilities and capabilities include the Combustion Research Facility (CRF) at Sandia National Laboratories (SNL), Advanced Photon Source at Argonne National Laboratory (ANL), Institute for Integrated Catalysis at Pacific Northwest National Laboratory (PNNL), detailed fuel chemistry expertise at the National Renewable Energy Laboratory, chemical kinetic modeling and mechanism development at Lawrence Livermore National Laboratory (LLNL), and the Spallation Neutron Source at Oak Ridge National Laboratory (ORNL), along with their high-performance computing (HPC) resources and initial work to utilize future exascale computing resources.

Subprogram Feedback

DOE received feedback on the overall technical subprogram areas presented during the 2018 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied.

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year?

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: acs918
Presentation Title: Advanced Combustion Systems and Fuels R&D Overview
Principal Investigator: Gurpreet Singh, U.S. Department of Energy

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:

The reviewer remarked that the program area was adequately covered and well described. This reviewer further recounted several items shown by the presenter: doubling of power density in ten years as related to engine trends; fuel economy increases as vehicles get larger; and regarding emissions trends, emissions have gone down while the number of vehicles and vehicle miles traveled have increased. The reviewer added that technologies to help the trend, which shows technology penetration, include gasoline direct injection (GDI); turbochargers (used with GDI); cylinder deactivation (CD); engine stop/start; transmissions (six or more speeds); continuously variable transmissions. Overall, the reviewer commented that the program has been successful and continues to be successful due to industry, academic, and government collaboration.

Reviewer 2:

This reviewer asserted that the strategy of Advanced Combustion Systems and Fuels R&D to reduce fuel consumption and emissions through higher efficiency and cleaner combustion-based power was clearly described. Further, the reviewer observed that a clear explanation of the impact of combustion-based vehicle power on the environment was also covered.

Reviewer 3:

This reviewer indicated that yes, the program area and overall strategy are well covered.

Reviewer 4:

This reviewer stated yes.

Reviewer 5:

The reviewer responded positively and observed brief but complete coverage of the program area, including overall strategy. The reviewer added that strategy was well described and seems very good.

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Reviewer 1:

The reviewer affirmed that both near- and long-term R&D are balanced to achieve the overall R&D goals of the program.

Reviewer 2:

This reviewer responded positively; the work with industry affects near-term effectively. There is solid long-term science that greatly contributes to advancing engine knowledge and technology.

Reviewer 3:

The reviewer explained that the program looks at mid-term (advanced spark ignition [SI] research) and long-term (low temperature combustion [LTC] research), fuel and fuel property effects, and aftertreatment for all combustion types. The reviewer continued that this balance is beneficial to the original equipment manufacturers (OEMs) and is well endorsed by them.

Reviewer 4:

This reviewer responded yes, and noted that a recent update to the Advanced Combustion and Emissions Control (ACEC) roadmap with priorities is integrated into plans. The reviewer also highlighted mixed mode for LD long-term and boosted SI for near-/mid- LD.

Reviewer 5:
The reviewer stated yes.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer commented that yes, the goals were well defined and developed with industry collaboration. Generally, this reviewer described the goals as a significant improvement in engine efficiency while maintaining low emissions and acceptable performance. The presenter showed how the research is successfully approaching these goals.

Reviewer 2:
The reviewer stated yes; it was good to see slides showing the amount of oil saved by investing in internal combustion engines (ICEs). This reviewer further commented that ICE is clearly shown to be relevant long-term.

Reviewer 3:
This reviewer commented that yes, the issues impacting current and future combustion-based vehicles were clearly identified and the challenges to meet future efficiency and emissions goals were adequately described.

Reviewer 4:
The reviewer responded positively and further commented that the challenges were identified and related to the overall system issues.

Reviewer 5:
This reviewer stated yes

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:
The reviewer reported that the presenter showed the areas of research that the program focusses on, the proposed research road map to reach the goals, and the technologies of focus that will allow that from fuels to engine parts to combustion systems to energy recovery systems to aftertreatment. This is a well thought out program that exemplifies how government and industry collaboration can benefit the United States as a whole.

Reviewer 2:
The reviewer replied yes; plans for developing enabling technologies for cleaner and more efficient combustion engines and fuels are clearly identified and outlined.

Reviewer 3:
The reviewer responded positively and added that plans seem solid and well thought out.

Reviewer 4:
This reviewer stated yes.

Reviewer 5:
This reviewer indicated yes and noted that the emission control R&D slide could have also included challenges of cold start and catalyst light-off.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:
This reviewer stated yes; the targets are carefully developed with industry input and are recently updated. The reviewer described goals as aggressive, but not unreasonable.

Reviewer 2:
The reviewer expressed that it is difficult to gauge progress on such a fine year-by-year timescale for such a large endeavor. However, this reviewer observed that year-to-year trends over the long haul are covered very adequately.

Reviewer 3:
This reviewer referenced an original baseline that had been changed to a more recent engine. The reviewer further commented that the program was benchmarked against the previous year and prior years. The changing baseline made the gains look smaller, but the reviewer explained this is well thought out because it gives a better technological baseline to compare against future research. The reviewer opined that the Program Manager should be commended for making this change because it will give honest, but not inflated, improvements.

Reviewer 4:
The reviewer stated yes.

Reviewer 5:
This reviewer commented that some information was presented.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:
The reviewer indicated yes; the projects seem well chosen to drive transportation technology in useful and effective directions.

Reviewer 2:
The reviewer explained that this program is focused on solving the technological barriers that the VTO office is trying to solve. The projects deal directly with improving the fuel consumption of engines and lowering the energy demands of vehicles.

Reviewer 3:
This reviewer responded positively and asserted that projects like SuperTruck II and Co-Optima are definitely addressing the “broad problems” that VTO is attempting to solve.

Reviewer 4:
The reviewer stated yes.

Reviewer 5:
This reviewer replied yes, to some degree. With respect to Co-Optima, the reviewer commented that near-/mid-term fuel for dilute downsized boosted SI should be the same fuel as that for longer-term mixed mode combustion.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO’s needs?

Reviewer 1:
The reviewer responded positively and was quite impressed with the leadership team, who are effective in leading a collaborative program. The leadership team’s history and expected future are examples of how government should work to improve society.

Reviewer 2:

This reviewer described the program as focused, well managed, and effective. Overall engine efficiency has increased significantly. The reviewer further explained that, thanks to this program, overall understanding of LTC concepts have gone from a science experiment to commercially viable (during parts of the engine map), and low-temperature aftertreatment (LTAT) that did not look possible now appears to be on the horizon.

Reviewer 3:

The reviewer asserted that the program area is very focused, well managed, and generally effective.

Reviewer 4:

The reviewer stated yes.

Reviewer 5:

This reviewer stated yes.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:

The reviewer asserted that all of the projects are well run and very strong.

Reviewer 2:

This reviewer commented that the program is extremely strong in all technical areas of need. The program manager is good at getting collaboration for industry and academia and it shows in the areas of research and research results. The only weakness observed by the reviewer was that the academic participation, while significant, was not as strong as the industry participation.

Reviewer 3:

The reviewer highlighted close involvement with industry, university, and lab teams as a strength. Further, this develops collaborative efforts toward major technical barriers. This reviewer also noted consideration of both LD and HD segments requirements. The reviewer described the tendency to emphasize collaboration to an extent that the overhead of coordination can become significant as a weakness.

Reviewer 4:

Key strengths observed by this reviewer include engagement of wide-range of resources from government laboratories, academia, and industry to tackle problems via a variety of projects and working groups. The reviewer commented that the program area actively seeks out and engages stakeholders to ensure that research remains focused on what all agree is important. However, coordination between labs and leveraging of their different strengths, while much better today than just a few years ago, could still be improved upon, as could encouragement of collaborative research projects between these labs and industry. The reviewer suggested that improved paths towards implementation of government-created tools and methodologies in the commercial sphere should be created and streamlined. Forums like Cross-cut Lean Exhaust Emissions Reduction Simulations (CLEERS) and Advanced Engine Combustion (AEC) memorandum of understanding (MOU) are excellent examples of ways to share DOE learning with industry and how to provide a feedback mechanism to guide future research so that it remains relevant. The reviewer further indicated that projects like Co-Optima show a degree of coordination between the national laboratories that was sadly lacking just a few years ago.

Reviewer 5:

This reviewer described world-class researchers and research facilities as key strengths. A weakness identified by the reviewer is the ability to turn the fundamental research into something that will impact OEM product, and added that the 2025/2030 time frame is aggressive to impact OEM product plans.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:

The reviewer remarked that the program's projects use technically feasible, but novel and innovative, approaches to solving the problems of increasing fuel efficiency in modern day vehicles while keeping the performance acceptable and the emissions low. Just this year, two auto manufacturers announced that they are producing vehicles using technologies developed in this program, which just 5 years ago were not thought possible due to the technical barriers. This is a testament to the diligence and hard work of the DOE Program Manager.

Reviewer 2:

This reviewer indicated yes and thought this is an example of how government agencies should manage and drive technical solutions.

Reviewer 3:

The reviewer stated yes.

Reviewer 4:

This reviewer stated yes.

Reviewer 5:

Although these projects are well reasoned and logical ways to approach the issues being addressed, the reviewer was not exactly sure they represent novel approaches.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:

As noted previously by this reviewer, one of the strengths of this program is the degree to which partners in academia and industry have been combined with government resources to attack the problems at hand.

Reviewer 2:

This reviewer responded positively and observed very effective engagement of industry and university partners including OEMs, Tier 1 suppliers, and other suppliers.

Reviewer 3:

The reviewer commented that the program has engaged partners in industry and academia. The program managers regularly meet with their partners to discuss progress and program goals and are well covered in this area.

Reviewer 4:

This reviewer described collaboration with LD OEMs as strong.

Reviewer 5:

The reviewer stated yes, but suggested better engagement with more universities to provide proper human resources to the industry in the future. This reviewer further commented that support to universities is relatively low-cost compared to national laboratories.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:

The reviewer indicated yes; the combination of collaborative research programs and information sharing forums appeared to be very effective.

Reviewer 2:
This reviewer stated yes and nicely done. Further, very effective collaboration was observed by the reviewer.

Reviewer 3:
The reviewer explained that program managers have set up several avenues for industry and academia to collaborate with them. This collaboration is how they have been successful in achieving their goals.

Reviewer 4:
The reviewer commented yes and noted many interactions and collaborations among national laboratories.

Reviewer 5:
This reviewer remarked that the U.S. Council for Automotive Research (USCAR) and U.S. Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) are good approaches to maintaining awareness for both teams (DOE and industry).

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:
No major gaps were found by this reviewer.

Reviewer 2:
No significant gaps are noted, but the reviewer suggested that an emphasis on eliminating barriers towards early and fast commercialization of tools and learning should be maintained and fostered.

Reviewer 3:
This reviewer reported that in recent years, due to budget cuts beyond the program managers' control, funding to LTC techniques and LTAT has decreased.

Reviewer 4:
It was unclear to the reviewer how the "kinetically controlled" combustion mode would be achieved. Further, the reviewer commented that this mode is essentially homogeneous charge compression ignition, which has not been working out well in practical application so far.

Reviewer 5:
The reviewer asserted that addressing cycle emissions, including cold start, should be increased.

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:
This reviewer commented that all the topics have been addressed well.

Reviewer 2:
The reviewer stated no.

Reviewer 3:
There were no topics inadequately addressed observed by this reviewer.

Reviewer 4:
This reviewer suggested that greater consideration of promoting ways that combustion-based power can be merged in a more effective way in the trend towards greater electrification of power trains could be pursued, e.g., range extenders, etc.

Reviewer 5:
The reviewer stated yes and referenced prior comments.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:
The reviewer explained that the budget seems adequate to keep the needs in hand, though no one would complain about more funding.

Reviewer 2:
This reviewer noted the cost of lean aftertreatment.

Reviewer 3:
The reviewer highlighted controls as they might aid in application of LTC combustion concepts to enhance stability over the entire operating range of the engine. This reviewer also indicated that integration of multiple alternative fuels in future engines or even more complex hybrid power trains could be potential funding opportunities.

Reviewer 4:
This reviewer remarked that more effort in LTC and LTAT are needed, and opined that this is the next area of research that will be needed to achieve DOE goals.

Reviewer 5:
Many studies on chemical kinetics were observed by this reviewer, who added that there do not seem to be as many spray studies.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:
This reviewer observed a great approach and stated to keep up the good work.

Reviewer 2:
The reviewer indicated not at this time.

Reviewer 3:
This reviewer stated not applicable.

Reviewer 4:
As LTC becomes more prevalent, this reviewer explained that fuel properties will be more important. Subsequently, the reviewer suggested that DOE needs to engage fuel manufacturers more.

Reviewer 5:
The reviewer recommended making it easier for multiple labs to enter into collaborative research arrangements (e.g., cooperative research and development agreements [CRADAs]) with industry might help reduce barriers and promote better leveraging of the different strengths of the various national laboratories.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:
The reviewer commented to keep going.

Reviewer 2:
The reviewer stated this is not applicable.

Reviewer 3:
This reviewer suggested to continue addressing barriers to production implementation of new ICE technologies.

Reviewer 4:
The reviewer advised to continue the trend towards building collaborative research programs and forums for combining industry, government, and university research.

Reviewer 5:
A larger budget for combustion and aftertreatment was recommended by this reviewer.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 1-1—Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
acs001	Heavy-Duty Low-Temperature and Diesel Combustion & Heavy-Duty Combustion Modeling	Mark Musculus (SNL)	1-15	3.75	3.75	3.25	3.38	**3.64**
acs002	Light- and Medium-Duty Diesel Combustion	Stephen Busch (SNL)	1-20	3.25	3.13	3.63	3.00	**3.20**
acs004	Low-Temperature Gasoline Combustion (LTGC) Engine Research	John Dec (SNL)	1-24	3.30	3.50	3.40	3.20	**3.40**
acs005	Spray Combustion Cross-Cut Engine Research	Lyle Pickett (SNL)	1-30	3.75	3.67	3.75	3.58	**3.69**
acs006	Gasoline Combustion Fundamentals	Isaac Ekoto (SNL)	1-35	3.10	3.00	3.30	2.80	**3.04**
acs010	Fuel Injection and Spray Research Using X-Ray Diagnostics	Christopher Powell (ANL)	1-40	3.50	3.40	3.40	3.50	**3.44**
acs011	Advances in High-Efficiency Gasoline Compression Ignition	Steve Ciatti (ANL)	1-45	3.67	3.67	3.50	3.67	**3.65**
acs012	Model Development and Analysis of Clean & Efficient Engine Combustion	Russell Whitesides (LLNL)	1-48	3.60	3.40	3.70	3.50	**3.50**
acs013	Chemical Kinetic Models for Advanced Engine Combustion	Bill Pitz (LLNL)	1-52	3.90	3.70	3.60	3.60	**3.73**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
acs015	Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes	Jim Szybist (ORNL)	1-56	3.50	3.60	3.60	3.60	**3.58**
acs017	Accelerating Predictive Simulation of Internal Combustion Engines (ICEs) with High-Performance Computing (HPC)	K Dean Edwards. (ORNL)	1-60	3.50	3.33	3.58	3.25	**3.40**
acs022	Joint Development and Coordination of Emissions Control Data and Models (Cross-cut Lean Exhaust Emissions Reduction Simulations [CLEERS] Analysis and Coordination)	Josh Pihl (ORNL)	1-64	3.75	3.50	3.67	3.33	**3.56**
acs023	CLEERS: Aftertreatment Modeling and Analysis	Yong Wang (PNNL)	1-70	3.25	3.19	3.38	3.25	**3.23**
acs027	Next-Generation Selective Catalytic Reduction (SCR)-Dosing System Investigation	Abhijeet Karkamkar (PNNL)	1-77	2.93	2.43	2.71	2.42	**2.59**
acs032	Cummins-ORNL Emissions Cooperative Research and Development Agreement (CRADA): NO_x Control & Measurement Technology for Heavy-Duty Diesel Engines, Self-Diagnosing SmartCatalyst Systems	Bill Partridge (ORNL)	1-83	3.42	3.33	3.25	3.33	**3.34**
acs033	Emissions Control for Lean Gasoline Engines	Todd Toops (ORNL)	1-88	3.67	3.50	3.58	3.42	**3.54**
acs052	Neutron Imaging of Advanced Transportation Technologies	Martin Wissink (ORNL)	1-93	3.20	3.20	3.10	2.70	**3.13**
acs054	Rapid Compression Machine (RCM) Studies to Enable Gasoline-Relevant Low-Temperature Combustion	Scott Goldsborough (ANL)	1-98	3.20	3.20	3.50	3.20	**3.24**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
acs056	Fuel-Neutral Studies of Particulate-Matter Transport Emissions	Mark Stewart (PNNL)	1-102	3.57	3.29	3.36	3.08	**3.34**
acs075	Advancements in Fuel Spray and Combustion Modeling with High-Performance Computing (HPC) Resources	Sibendu Som (ANL)	1-107	3.50	3.50	3.67	3.33	**3.50**
acs085	Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization	Todd Toops (ORNL)	1-113	3.42	3.25	3.33	3.33	**3.31**
acs093	Lean Miller Cycle System Development for Light-Duty Vehicles	Paul Battiston (General Motors)	1-118	3.80	3.60	3.70	3.30	**3.63**
acs100	Engine Improving Transportation Efficiency through Integrated Vehicle, and Powertrain Research—SuperTruck II	Justin Yee (Daimler Trucks North America)	1-123	3.40	3.20	3.30	3.00	**3.24**
acs101	Volvo SuperTruck II: Pathway to Cost-Effective Commercialized Freight Efficiency	Pascal Amar (Volvo Trucks North America)	1-127	3.40	3.30	3.70	3.20	**3.36**
acs102	Cummins-Peterbilt SuperTruck II	Michael Ruth (Cummins-Peterbilt)	1-131	3.86	3.64	3.64	3.71	**3.71**
acs103	Development and Demonstration of a Fuel-Efficient Class 8 Tractor & Trailer SuperTruck	Russell Zukouski (Navistar)	1-136	3.14	2.86	2.79	2.57	**2.88**
acs116	Advanced Non-Tread Materials for Fuel-Efficient Tires	Lucas Dos Santos Freire (PPG Industries)	1-141	3.20	3.10	2.70	3.20	**3.09**
acs118	Advanced Emission Control for High-Efficiency Engines	Yong Wang (PNNL)	1-145	3.08	3.08	3.25	2.83	**3.07**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
acs119	Development and Optimization of a Multi-Functional SCR-DPF (Diesel Particulate Filter) Aftertreatment System for Heavy-Duty NO_x and Soot Emission Reduction	Ken Rappe (PNNL)	1-151	2.93	3.07	3.00	2.79	**2.99**
acs120	Enabling Lean and Stoichiometric Gasoline Direct-Injection Engines through Mitigation of Nanoparticle Emissions	Will Northrup (U. of Minnesota)	1-157	3.43	3.36	3.14	3.36	**3.35**
acs121	A High Specific Output Gasoline Low-Temperature Combustion Engine	Hanho Yun (General Motors)	1-163	3.63	3.63	3.25	3.38	**3.55**
acs122	Solenoid Actuated Cylinder Deactivation Valvetrain for Dynamic Skip Fire	Hermes Fernandez (LLC Delphi Automotive Systems)	1-167	3.25	3.00	3.38	2.88	**3.09**
acs123	Temperature-Following Thermal Barrier Coatings for High-Efficiency Engines	Tobias Schaedler (HRL Laboratories)	1-171	3.17	3.25	3.33	3.17	**3.23**
acs124	SuperTruck II—PACCAR	Carl Hergart (PACCAR)	1-176	3.25	2.94	3.06	3.13	**3.05**
Overall Average				**3.41**	**3.29**	**3.35**	**3.20**	**3.31**

Presentation Number: acs001
Presentation Title: Heavy-Duty Low-Temperature and Diesel Combustion and Heavy-Duty Combustion Modeling
Principal Investigator: Mark Musculus (Sandia National Laboratories)

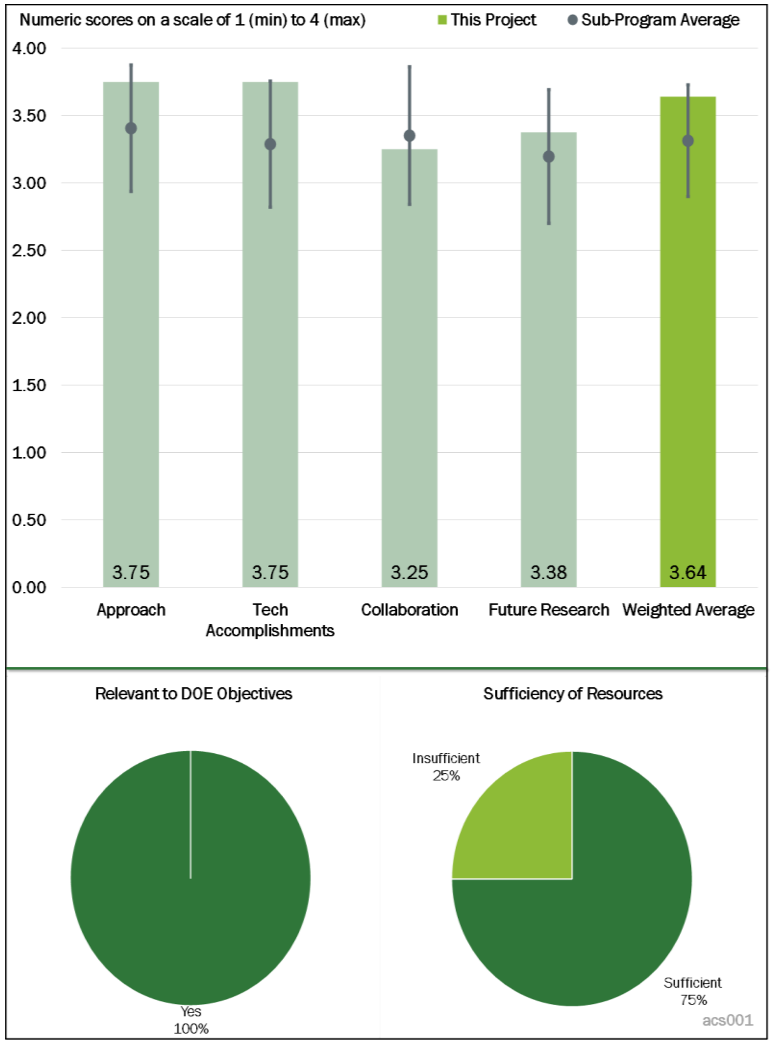

Figure 1-1 - Presentation Number: acs001 Presentation Title: Heavy-Duty Low-Temperature and Diesel Combustion and Heavy-Duty Combustion Modeling Principal Investigator: Mark Musculus (Sandia National Laboratories)

Presenter

Mark Musculus, Sandia National Laboratories

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that this project demonstrates a well-balanced approach that combines optical engine diagnostics and multi-dimensional engine simulations to understand several key problems in heavy-duty diesel (HDD) combustion system understanding and, hence, design. Examining how multiple injections interact to modify noise, emissions, and efficiency in diesel combustion is particularly important and of great practical interest to improving future production diesel engines. The reviewer commented that the fundamental work connecting polycyclic aromatic hydrocarbon (PAH) and soot distributions is also very important and exciting in its potential to impact future soot modeling capabilities. The reviewer commended the researcher and his team for conducting work that impacts understanding of both conventional mixing-controlled as well as advanced low-temperature combustion (LTC) diesel combustion strategies. The reviewer said that the program is indeed “well-designed” and has already demonstrated the feasibility of its approach to advancing understanding and addressing some of the key “technical barriers” facing diesel combustion system designers today.

Reviewer 2:

The reviewer observed very well thought-out experimental plans based on modeling and previous experiments. This reviewer observed that there seems to be careful determination of operating conditions to clarify particular areas needing improved understanding, which looks to result in relevant conditions.

Reviewer 3:

The reviewer said that the approach to this project is both experimental and computational. The thought about experimental design was clearly demonstrated with the use of sooting threshold conditions and multiple PAH detection to address soot formation states. Additionally, the reviewer noted that the use of computational fluid dynamics (CFD) to help interrogate field quantities was/is a good approach. The reviewer said that going beyond CFD of sprays to engine-combustion CFD was discussed in the Q&A portion of the presentation.

Reviewer 4:

The reviewer said that the project team combined the laser diagnostics and numerical simulation to investigate the impacts of multiple injection on soot formation and oxidation in diesel engines, and ultimately developed a conceptual model for it. However, due to the complexity of the problem, it is very difficult to identify the influence of a single physical mechanism. The reviewer commented that it will be better to investigate the similar phenomena in a well-controlled experimental setup at first to isolate the multiple physics, and then apply to engine conditions with additional physics. Ideally, the three-dimensional (3D) combustion CFD may contribute to reveal the detailed physics behind the experimental images. The reviewer said that unfortunately, it seems that 3D combustion CFD itself has some difficulty to reproduce the process due to a lack of accurate numerical models, especially the soot model. All of these factors cast a shadow over the whole problem. The reviewer suggested that the project team may want to improve the soot model, or develop a smart way to dig into the details by using the present laser diagnostics techniques and 3D combustion CFD.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that this project has been ongoing for a long time, but with continued focus on generating science-based conceptual understanding of diesel combustion. The results presented continue to move the understanding at a good pace. The reviewer noted that publications and communication of the project results are easily found, indicating good knowledge transfer from this project to the engine combustion community. The reviewer noted that this project is one of the top DOE funded combustion projects that has direct and long-lasting relevance to the HD OEM. In-cylinder understanding of the physical processes of mixing controlled combustion systems is paramount in the HD sector. The reviewer said that mixing controlled combustion is dominant and will not be displaced by kinetically controlled combustion concepts for a multitude of technical, scientific, and economic reasons. More DOE effort needs to be pushed toward mixing controlled combustion system scientific understanding, computational modeling, and technology generation. The reviewer recommended continued strong support of this project and consider increasing its budget and scope.

Reviewer 2:

The reviewer stated that the progress of this project is great. The project team developed a combined planar PAH laser-induced fluorescence (LIF) and soot laser induced incandescence (LII) technique for in-cylinder visualization, particularly showing the interactions with the piston wall. Effects of nitrogen dilution at single injection conditions, different multiple inject strategies (close-coupled and long-dwell), and swirl have been examined in detail. The reviewer pointed out that different behaviors of PAH formation and soot under close-coupled and long-dwell have been highlighted. The 3D combustion CFD qualitatively reproduced the ignition processes of conventional and LTC diesel combustion. The reviewer said that more simulation results about PAH formation, soot formation, and oxidation are expected.

Reviewer 3:

The reviewer said that progress and accomplishments continue to be very strong for this project. The proof to this reviewer is how the research to date has already impacted how some firms design combustion systems. Some firms have utilized the PAH/soot mapping results previously presented to improve modeling soot formation in diesel simulations. The reviewer remarked that while some of the improvements are based on other sources, the research obtained from this project has played a key role in the ability to double the accuracy of soot predictions in the past 3 years. The reviewer said that significant results have already been posted and continue to be obtained towards a more fundamental understanding of multi-pulse injection/combustion dynamics and steady progress year-to-year demonstrated.

Reviewer 4:

The reviewer said that the test facility is unique, and is well-applied to the most critical areas needed research. The reviewer commented that nice progress has been made this year.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the collaboration and coordination within the team is excellent. There is a close connection between the optical engine studies done at SNL and the modeling work done at the University of Wisconsin-Madison (UW). We also see strong evidence of the collaboration and coordination with engine and injector manufacturers. From the presentation, it is not clear how the model development work is currently or will be coordinated with code vendors so that improved physical models that might be developed under this project will find their way into commercial tools used by industry, nor is the project's collaboration with Lund described in any detail. It would also be interesting to hear about any cross-coordination between the optical engine work being done under this project with the spray diagnostics work being done by other researchers at SNL or how the PAH/soot studies are impacting chemistry development at Livermore for example.

Reviewer 2:

The reviewer commented that the collaborations between SNL and UW-Madison, and between teams within SNL, are remarkable. The reviewer did not see any information about the collaborations between SNL and industrial partners. Possibly they have provided solid supports through providing hardware and software. Feedback from and/or involvement with these industrial partners may bring in some insightful ideas.

Reviewer 3:

The reviewer stated that this work is part of the MOU work, and thus has regular and effective input from industry, national laboratory, and academic partners. This is a good example of how collaboration should work. The reviewer noted that there is an upcoming SME paper ICEF2018-9733 with data that may be relevant or useful for the project team and will be presented in San Diego in November.

Reviewer 4:

Collaboration in this project seems to be mainly between SNL and the UW. The reviewer indicated that the work seems to be well-coordinated even with the limited number of collaborators.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that although only briefly described in presentation, the proposed work appears very logical and addresses the key issues remaining in understanding multi-pulse injections and their impact on combustion and emissions. The combined experimental and analytical work promises to form a good basis for the conceptual model being developed. It is perhaps less clear how, or even if, it is the intent of the project to address the operating range limitations of LTC that prevent that strategy from making it into production HDD engines.

On a more fundamental note, one aspect of optical engine research has always troubled this reviewer is how optimized is the combustion system is that is being studied. Production diesel engines are, hopefully, based on the best (within the limits of current technology) optimized combustion systems possible. It is not clear to the reviewer what steps have been taken to ensure that the same is true for the optical engine combustion systems being studied, whether the injector, piston bowl, swirl level, etc. are well matched. SNL has developed the technique to utilize non-flat bowl shapes in optical engines, and it might be interesting to perform a bowl/injector optimization study, perhaps in conjunction with OEM partners or even UW, to ensure that future studies are looking at how a fully optimized combustion system is behaving.

Reviewer 2:

The reviewer stated that the plan to emphasize simulations next is correct. As more simulations emerge, further experiments may be suggested. The combination of simulation and data are very strong.

Reviewer 3:

The proposed future research on the three areas listed (mixing, ignition/combustion, and emissions process) are exactly on target, according to the reviewer. These are difficult areas to work toward, however. The review presentation did not get into great detail about the physical work tasks associated with each of the three areas. The reviewer is unclear whether this may be documented somewhere else or is yet to be fully formulated. Additional insight into the proposed tasks to research on these three areas would be helpful to provide critical feedback.

Reviewer 4:

According to the reviewer, the project team has identified the current gaps in experiment and numerical simulation, and has developed a clear and feasible plan to address these issues. But there is no description about improvements in experimental and simulation techniques

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer comments that the multiple injection technique is one of the most promising technologies for improving efficiency and emission of ICEs. Understanding of its mechanism is of great importance for optimizing the internal combustion (IC) engines using this technique. It is also a challenging condition for the modern soot models. This work intends to reveal the fundamental mechanism of the multiple injection effects on mixing and soot formation/oxidation by developing a conceptual model. The work may lead to improvements in spray models and/or soot models for 3D combustion CFD. The outcomes of the present project will benefit the engine industry by improving the physical understanding and potentially improving 3D combustion CFD models.

Reviewer 2:

The reviewer commented that this project is very relevant to improving diesel engine combustion, improvement of efficiency, and reduction of emissions. The information developed here will help engine designers directly, and by improving simulation ability, will provide tools for engine designers and developers.

Reviewer 3:

According to the reviewer, yes, this project supports the overall DOE objectives. Enhanced scientific understanding of diesel and mixing-controlled combustion processes clearly allows better optimization of combustion systems for increased efficiencies (reduced energy consumption) at the same or reduced emissions levels. Knowledge gained in this project is additionally vetted against CFD tools, which can enable a direct transfer to industry via these simulation tools.

Reviewer 4:

According to the reviewer, the research supports the DOE's objectives of driving up efficiency while driving down emissions.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The resources seem appropriate given the shift toward simulation. However, if future developments require more experimental work, there may be a need to restore some of the past funding levels.

Reviewer 2:

The reviewer commented that the team has the access to the world top facilities of laser diagnostic and optical engine. The team consists of top experts in laser diagnostic, diesel engine, and 3D combustion CFD and is rich with experience.

Reviewer 3:

Because the SNL experiments are in an optical engine with a multi-hole combustion system, the CFD side of the project should quickly be following suit to achieve the project milestones in a timely manner. Presently, the CFD work focuses on single-spray simulations. The reviewer suggested adding scope/resources or quickly moving toward engine-combustion CFD simulations to really extract understanding and play on the different strengths/weaknesses of the experimental and CFD methods. Gaining access to HPC resources may be an easy way to accelerate the computational side of the project without adding substantial cost.

Reviewer 4:

Per the reviewer, resources being utilized for this project are sufficient to achieve the stated milestones in a timely fashion.

Presentation Number: acs002
Presentation Title: Light- and Medium-Duty Diesel Combustion
Principal Investigator: Stephen Busch (Sandia National Laboratories)

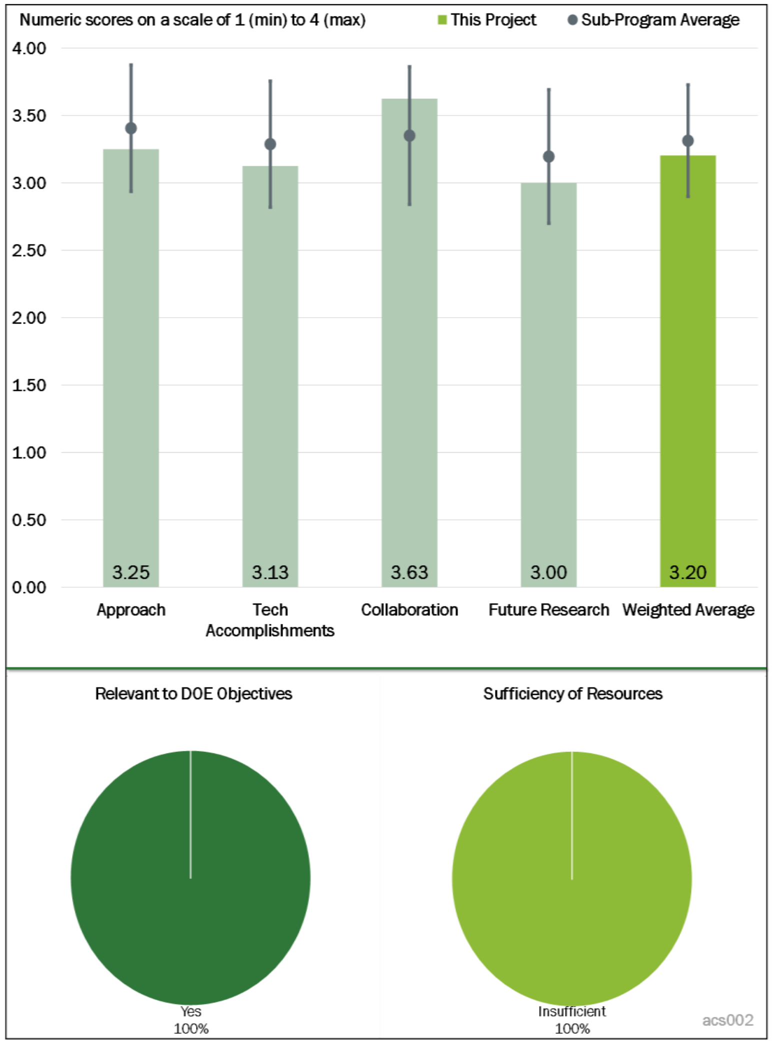

Figure 1-2 - Presentation Number: acs002 Presentation Title: Light- and Medium-Duty Diesel Combustion Principal Investigator: Stephen Busch (Sandia National Laboratories)

Presenter

Stephen Busch, Sandia National Laboratories

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project seemed to have well-coordinated experimental and modeling. The reviewer stated that with more funding, it would be of interest to investigate the fundamentals behind other geometrical changes than just conventional versus stepped lip piston, such as various squish clearances and other features.

Reviewer 2:

The reviewer considered the approach to this work is quite good, and considering the redirection and course change, well communicated and documented. Combining optical engine experiments, CFD, and metal engine experiments demonstrates the use of almost all the combustion tools available for project execution. However, because the project has been recently redirected, future clarification of critical tasks is expected.

Reviewer 3:

Past experimental work on flow visualization in the bowl rim area, and the associated CFD focuses on better understanding the influence of piston design on flowfield behavior, appears to be valuable toward one project objective of developing an engineering conceptual model for relating spray targeting to emissions formation in-cylinder. One question that arises though is the influence of piston speed and load on these local flowfield structures. Per the reviewer, more work could be done to address that shortcoming in the future.

Regarding the second part of this project, targeting better understanding of catalyst light-off, it is not clear what type of conceptual model is in the works for engineering purposes. The reviewer stated that this project has experienced recent redirection and thus it may be too soon to have the conversation about the conceptual model development.

Reviewer 4:

The reviewer commented that the technical barrier was well pointed out, although the reviewer is not sure what level of understanding of physics and model verifications are pursued. Ideally, a full optical engine running at conventional conditions will be needed, which is challenging technically. It is not very clear if the work is to address such problems.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the combustion image velocimetry proved to be very insightful and that there was a good description of recirculating flow structures effects.

Reviewer 2:

The reviewer considered the progress on this project strong, especially considering the flux and redirection. The piston bowl portion of the project is a good example of fundamental combustion system physical understanding. The ability to identify flow fields and relate them to mixing, heat release, and emissions is demonstrated clearly. Engine OEMs develop combustion systems and regularly understand the net effects, but have lower levels of access to in-cylinder experimental understanding. The movement of the project towards using CFD is a good step towards enabling verification of this project's experimental results. Spray-wall interactions are critical in mixing-controlled combustion system design and this reviewer recommends the experimental work start again once the move to the 100 meter bore platform has been made. There is a wide body of knowledge on spray-wall combustion system design, so the reviewer suggested the project reach out to industry for continued engagement for enhanced understanding and alignment. Preliminary data for cold-start operation shows a quick transition to the second aspect of the project and its redirection.

The reviewer pointed out that mixing controlled combustion is dominant and will not be displaced by kinetically controlled combustion concepts for a multitude of technical, scientific, and economic reasons. The reviewer said that more DOE effort needs to be pushed toward mixing controlled combustion system scientific understanding, computational modeling, and technology generation. The reviewer recommended continued strong support of this project and to consider increasing the budget and scope.

Reviewer 3:

This project was redirected twice and the reviewer suspected that such changes impacted the technical accomplishments during the last year. A new thrust of cold-start light-off was added to the project, and like any new thrust, slowed down progress. The project team and collaborators spent a significant amount of time analyzing optical engine data and employing CFD to help better understand some of their experimental observations. It would have been beneficial if additional optical engine data were available for various engine speeds and load conditions to augment the learning process. But again, the project was redirected twice and that may have limited the capability of the project team to execute additional experimental work.

Reviewer 4:

The reviewer commented that the overall accomplishments and progress look weak, although it seems that funding was a limiting factor.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the project coordination seems to be quite good. Coordination difficulty often increases as collaborator number increases, and there are six collaborating parties in this project. The roles of each party were clear and documented.

Reviewer 2:
The reviewer stated that the collaborations look good, overall. Having information available on the Engine Combustion Network (ECN) database is a good choice, so that others (outside the industry partners) can try the same practice. A line mentioning about CD-adapco was a little hard to understand. It is always a good idea to have multiple tools trying the same problem. The reviewer inquired if CD-adapco is reluctant to collaborate. There should not be any technical problem in processing engine geometry files to convert to mesh.

Reviewer 3:
According to the reviewer, this project was a clear collaboration and coordination with two LD companies, a HD company, and two software application companies. This team appears to be working well together in analyzing and extracting whatever understanding is possible from the experimental optic engine data.

Reviewer 4:
To this reviewer, it appeared to be a wide collaboration. The reviewer questioned what aspects can be accelerated, specifically on the Wisconsin Engine Research Consultants sub-contract.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the proposed future work plan seems to be good. Due to the project redirection, there is some uncertainty and likely a lower level of work that will be completed in fiscal year (FY) 2018, purely due to the prior project uncertainty. The reviewer is concerned about the plans to get the new 100 millimeter bore metal and optical engines up and going. This may take significant effort and time and reduce the ability to conduct the catalyst heating experimental activities. The reviewer recommended watching for this potential resource conflict.

Reviewer 2:
The reviewer said that it would be great to see more experimental work at varying engine speeds and loads, and also see a game plan for developing conceptual models for both the spray-wall interaction thrust and also the cold start light off thrust. The reviewer understood that the second thrust is a new one, but if the goal is truly to develop engineering level conceptual models, then possibly more attention to scaling key measurements/parameters to engineering understanding is worthwhile.

Reviewer 3:
The reviewer stated that including an aspect of high swirl versus moderate swirl could be useful for further insight.

Reviewer 4:
According to the reviewer, the plan makes sense only with the new optical engine waiting for funding approvals.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said yes, this project absolutely addresses DOE objectives. Each part focuses on enabling higher efficiency, low emission IC engine technology development though each part has a different focus. Studying the cold-start catalyst light-off from a scientific viewpoint with the hope of lighting off sooner by using the minimum amount of fuel will be a challenge, but nevertheless could be helpful toward the objective of engineering conceptual model with the hope of aiding the further development of advanced gasoline engine technology possibly including lean burn operation.

Reviewer 2:

The reviewer remarked yes, this project supports the overall objectives of the DOE. Per the reviewer, enhanced scientific understanding of diesel and mixing-controlled combustion processes clearly allows better optimization of combustion systems for increased efficiencies (reduced energy consumption) at the same or reduced emissions levels. The knowledge gained in this project is additionally vetted against CFD tools, which can enable a direct transfer to industry via these simulation tools.

Reviewer 3:

The reviewer stated that this project is fundamental to efficiency and emissions optimization for multiple paths of IC engines in future.

Reviewer 4:

The reviewer commented that, yes, the project supports DOE objectives to reduce engine emissions and improve fuel economy.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that this project budget seems a little low considering all of the project work effort by the various partners. But, the project team did comment that their national laboratory received approval to bring on-line a modern multi-cylinder engine via DOE funding. So, the reviewer is unsure if the budget truly is insufficient or not. The presentation generally pointed toward a lack of funding.

Reviewer 2:

According to the reviewer, this project should be in line with 2017 budget, which was $800,000-$950,000 per year.

Reviewer 3:

The reviewer commented that a new optical engine is a critical piece for the success of the project.

Reviewer 4:

The reviewer has indicated that the resources for this project are insufficient due to the new 100 millimeter bore platforms. This is a substantial effort and if significant money and labor are not allocated to this, the present funding of $200,000 will not work. The reviewer assumed that once the 100 millimeter bore approval is gained, then the resources and funding will be appropriately matched.

Presentation Number: acs004
Presentation Title: Low-Temperature Gasoline Combustion (LTGC) Engine Research
Principal Investigator: John Dec (Sandia National Laboratories)

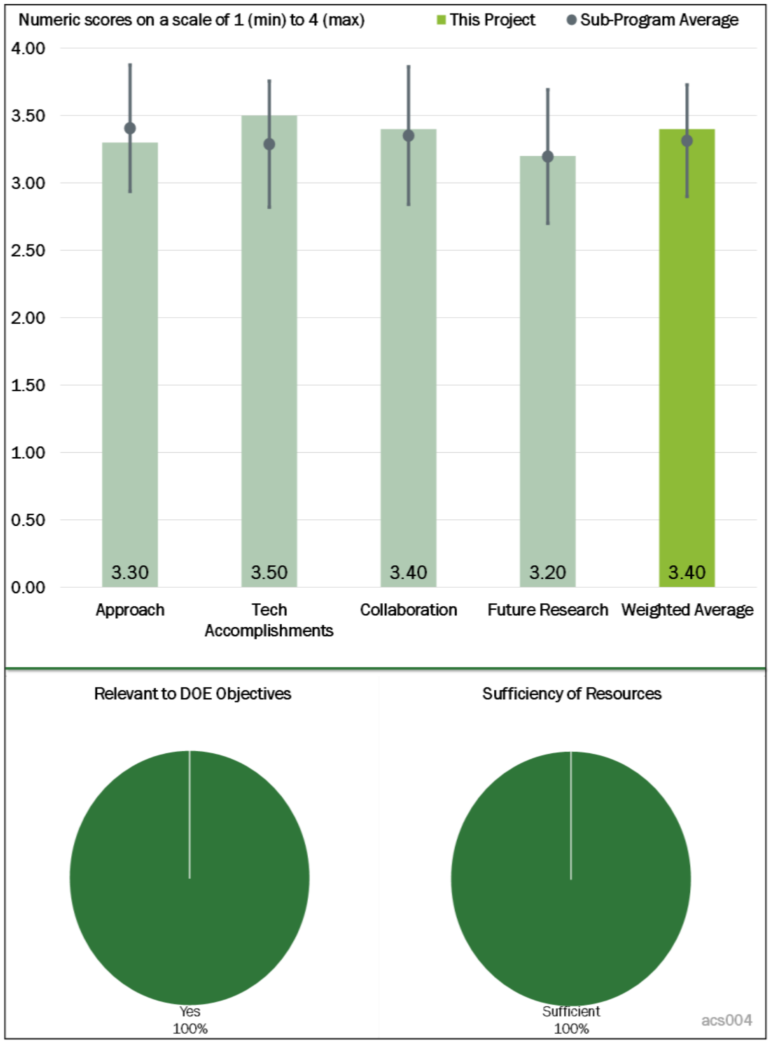

Figure 1-3 - Presentation Number: acs004 Presentation Title: Low-Temperature Gasoline Combustion (LTGC) Engine Research Principal Investigator: John Dec (Sandia National Laboratories)

Presenter
John Dec, Sandia National Laboratories

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer said that LTC has been a concept promising very good efficiencies with very low emissions for decades, but has been plagued by the inability to control combustion timing, particularly at high loads. Gasoline, while widely used for SI engines, has potential benefits to compression ignition (CI) engines as well in terms of emissions and potential future costs as the transportation landscape continues to change. This project does an excellent job of exploring the concepts of LTGC through a wide range of studies involving metal and optical engines and, increasingly, multi-dimensional engine simulation. Of particular note is the progress made in controlling combustion timing through developing an apparently successful, although yet to be fully explored, technique based on introducing controlled amounts of an ignition enhancing additive during each engine cycle as required. Overall, the approach taken is very effective in addressing the many technical barriers to using LTGC via very systematic research utilizing resources of government national laboratories, universities, and industry, and makes a compelling story that might just demonstrate the practicality of this technology for future production IC engines.

Reviewer 2:
The reviewer commented that the approach is generally very good. It seems that sufficient data have been taken and that optical measurements are in order. As an example, the CFD work from State University of New York at Stony Brook (Stony Brook) should be compared to the current engine, and not data from 2012, which the reviewer presumed is a different engine. The presentation included a slide on phi sensitivity (Slide 30) that was not in the material given to the reviewers. When the author presented the slide, it was accompanied by a comment that “This slide is complicated and I do not have time to explain it,” which was not helpful to this reviewer.

Reviewer 3:

Per the reviewer, this project is very well developed. It brings together a range of collaborators with wide-ranging expertise to address the problem of understanding the practicality of low-temperature gasoline combustion (LTGC) technologies. In the experiments, the PI uses an optical and metal single cylinder engine to develop a better understanding of LTGC and to leverage the capabilities of the collaborators that will ultimately facilitate transfer of the results to industry. The SNL LTGC laboratory is a world leader in engine testing; the great benefit is derived from results reported to achieve the desired understanding that can make viable LTGC a reality. The reviewer pointed out that CFD modeling is included, and new combustion timing control techniques are investigated. Using 88-octane research gasoline (RD587) fuel is particularly appropriate to reduce uncertainty in 10% ethanol content gasoline (E10) compositions that can often arise.

The approach of using the project team’s single cylinder engine designs is quite appropriate and very useful. The reviewer stated that it would perhaps be good to highlight how results from single-cylinder engine tests would provide the type of data that the OEMs will find useful in engine design. It would also perhaps be useful for the project team to articulate the link to multi-cylinder configurations that the OEMs would find most useful. Although this has been done in past work, it would not hurt to mention the link. The reviewer considered the comparisons between the surrogates and the model fuel investigated in the experiments very appropriate and significant.

The reviewer noted that the presentation noted a new collaboration on CFD with a university partner, and recommended presenting more on this, because national laboratories are developing robust capabilities for modeling in-cylinder processes, and the PI noted collaborations with ANL to compare his engine data with ANL predictions. The reviewer stated that this is good and that more should be presented on this. The reviewer questioned what the added university capabilities bring to the project that the ANL collaborations do not. Presumably, with ANL, CONVERGE is being used.

Regarding collaborations with LLNL on kinetic models, the reviewer stated that more should be provided on precisely how the engine results can inform development of kinetic models. Certainly, the engine data are appropriate and novel. However, precisely how they will fold into development of kinetic models is not clear.

Reviewer 4:

The reviewer said the idea of using a second additive fluid to control crank angle position at which 50% of heat is released (CA50) is a good one. However, before too many resources (time, money) are spent on developing and researching this idea, quick experiments should be conducted to evaluate both the technical benefits and the commercial viability of such a concept. CA50 needs to change in the order of 2-3 engine cycles (100 -300 milliseconds). Having a LD customer fill a second fluid at oil-change intervals is an idea that has been met with very high resistance.

Reviewer 5:

The reviewer remarked that using large eddy simulation (LES) CFD model can offer insight to engine behaviors, but asked how it is relevant to simulate one geometry and compare it to a different geometry in the engine. The reviewer commented that the new approach of using an ignition additive may finally address the combustion phasing problem.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that accomplishments and progress in this program are quite remarkable, especially in the context of the amount of effort that has been expended over the years by other researchers to achieve the level of control needed to make LTC practical over the entire operating range needed for production engines. Adding CFD studies to understand turbulent mixing effects on stratification is particularly noteworthy, as are plans for optical engine studies; both should accelerate future progress of this project.

Reviewer 2:

The surrogate kinetic work is very good and important. The reviewer questioned what the additional computational overhead time that results when it is used. It seemed to the reviewer that with the variation of the mixing from cycle to cycle, as well as the variation of thermal stratification, phi sensitivity variation between fuels is something to minimize. Others have suggested using ethylhexyl nitrate (EHN) as an ignition improver. To this reviewer, it seemed that the potential use of additive-mixing fuel injection (AMFI) will supersede or minimize other concerns, like phi sensitivity.

Reviewer 3:

The reviewer stated that very good progress has been made, as follows: When applying LES to understand sources of thermal stratification, the reviewer questioned the role or potential of intake generated turbulence on the transient control of CA50, if thermal stratification, needed for control of CA50, is caused by intake generated turbulence. An improved surrogate for regular E10 fuel has been developed. Both this model and the LLNL model seem to work well. The reviewer said the relationship of phi sensitivity to octane sensitivity has been investigated and an electrolyte primer blend “Blend 3” has high phi sensitivity as well as high research octane number and high sulfur (S). A new concept has been developed for rapid control of CA50. According to the reviewer, the issue will be a transient response related to the additive delivery system, mixing of additive and fuel, and dead volume. These parameters should be quickly designed to make sure they can be easily engineered.

Reviewer 4:

The reviewer commented that the project has established a collaboration with a modeling group to assist in the explanation of the results. This is good. CONVERGE CFD software is being used. Because ANL is investing heavily in CONVERGE CFD for engine simulations, the reviewer questioned whether there are any collaborations with ANL. The reviewer noted some information on CFD “validation.” Because the in-cylinder environment is so complicated, precisely how validation can be accomplished with this engine configuration is unclear. If sub-models are needed in CONVERGE CFD, their uncertainties can be a factor in validation. The reviewer questioned whether there are any multiphase (e.g., spray/gas interactions) that is expected and included in the simulation.

The reviewer pointed out that the experimental comparisons between research gasoline for performance comparison (RD587) and the various surrogate blends is excellent. They show the value of the surrogates developed. Interestingly, the binary performs almost as good as the four-component system. This result provides a significant advantage in modeling (a two-component blend is far easier to deal with than a four-component blend). The reviewer noted that software for the conceptual development of combustion systems (CHEMKIN) simulations is being pursued. The reviewer questioned whether this is for the engine or, say, a homogeneous reactor or other combustion configuration with a low-dimensional transport.

Reviewer 5:

The reviewer stated that development of a unique fuel formulation to enable a certain combustion approach will not be commercially relevant. The combustion approach must be compatible with the full range of available retail market gasolines in order for a manufacturer to embrace it. Using the ignition additive is a good step, but the team must show it to be effective regardless of the fuel. The transient torque response requirements for LD applications are on the order of a hundred milliseconds, so an order of magnitude improvement in transient response is required. The ignition additive delivery system would have to be developed to reflect this requirement. The reviewer said that a claim of low particulates was made, but no results were shown that demonstrate this.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the kinetics work of LLNL and the CFD work at Stony Brook are strong contributions to this program.

Reviewer 2:

The reviewer commented that the collaborative team is very good, as it includes a combination of extensive engine experiments and collaborations with those doing CFD modeling. CFD modeling is almost a necessary/required component to make sense of the experimental results, and the project team has an excellent group of collaborators. The reviewer said it would be useful, perhaps, to say more about collaborations with national laboratories doing similar collaborations. The author mentioned ANL, for example. Of particular interest is precisely how the CFD modelers use the engine data and how the engine data inform development of surrogates.

Reviewer 3:

The reviewer said that collaboration has been very good in the past and is getting stronger with addition of Stony Brook for CONVERGE CFD studies. The reviewer stated that while some explanation of how LLNL kinetics, etc. research is being integrated into this project, the role of ANL's rapid compression machines (RCM) work is less understood and could be more clearly described. While OEM interaction on the smaller engine side is clear, there does not seem to be much interaction on the HD end of the spectrum and could be increased as this technology would definitely be of interest there as well.

Reviewer 4:

Per the reviewer, collaborations are adequate. Additionally, it is good to see the addition of a CFD partner to support the work.

Reviewer 5:

The reviewer stated that collaborations exist with General Motors Corporation (GM).

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The project team has identified a number of aspects that need additional work: cycle-to-cycle variations for higher fuel rates; how intake flows produce large scale turbulence and robust ignition; infrared (IR) imaging of fuel distribution; and closed loop feedback control system. The CFD modeling that notes "fuel sprays..." perhaps deserves further elaboration. Incorporating fuel sprays in engine simulations is an extremely difficult problem. A lot of groups have been working on this but without full success yet. The reviewer pointed out a question to close the gap between modeling and engine experiments is what do the modelers need that excellent engine testing here provides.

Reviewer 2:

The reviewer found that the proposed research moving forward is clearly presented and focuses on furthering understanding the AMFI control system, the role of multiple injections on combustion timing control, further CFD and optical studies on fuel stratification, and devising better mechanisms for CA50 control. All of these are vital areas of research to further the development of LTGC.

Reviewer 3:
Continued investigation into the use of the ignition additive is important to determine if this is a valid approach. The reviewer commented that an improved control system will contribute to this by investigating the transient torque response to be sure that it is fast enough.

Reviewer 4:
The reviewer said that some effort has to be expended to show potential for commercialization of the LTGC concept with the ignition enhancing fluid.

Reviewer 5:
The reviewer is puzzled with some of the future directions of this project. The reviewer understands that the objective of the research directed towards LD is for multi-mode combustion: kinetically controlled combustion at lighter loads, which is transitioned to active ignition at high loads. The reviewer questioned whether or not the transition between kinetically controlled and active ignition should be a focus of study. Also, as long as the project team is going to have an active ignition system, the reviewer questioned the use of the EHN system versus using that for CA50 control. Given that the project team will not pursue max load through kinetically controlled combustion for light load operation, the reviewer questioned why this is being pursued for medium-duty/HD operation.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said yes, from a broad perspective, this project will support the overall DOE objectives. The project focuses on LTC from the perspective of gasoline fueling engines under diesel-like conditions. The project is also relevant to multimode operation that can improve efficiencies of diesel engines. Aftertreatment costs are also expected to be reduced. The reviewer found all of this to be very nice.

Reviewer 2:
The reviewer commented that this program endeavors to advance efficiency and emissions goals of DOE and may also impact DOE alternative fuel scenarios as well.

Reviewer 3:
The reviewer found that potential performance gains and overall system greenhouse gas reductions through advanced combustion system with environmentally optimized fuels will be an important component of moving toward sustainable mobility.

Reviewer 4:
The reviewer said that questions remain regarding robustness to variation in market fuels, ambient environmental conditions, and transient response. The reviewer commented that this work will be relevant only when all of the barriers to implementation are addressed.

Reviewer 5:
According to the reviewer, engine efficiency can be improved significantly if this project is successful.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
It appears to the reviewer that resources are sufficient to achieve stated milestones and objectives.

Reviewer 2:
The reviewer stated that resources seem sufficient and the project team has had success with initiative to get additional support when needed.

Reviewer 3:
Per the reviewer, the funding is adequate and should not be increased.

Reviewer 4:
The reviewer commented that the stated milestones can be achieved.

Reviewer 5:
The reviewer stated that resources seem adequate although ultimate judgement would have to come from a cost/benefit analysis based on DOE’s investment relative to the commercialization potential.

Presentation Number: acs005
Presentation Title: Spray Combustion Cross-Cut Engine Research
Principal Investigator: Lyle Pickett (Sandia National Laboratories)

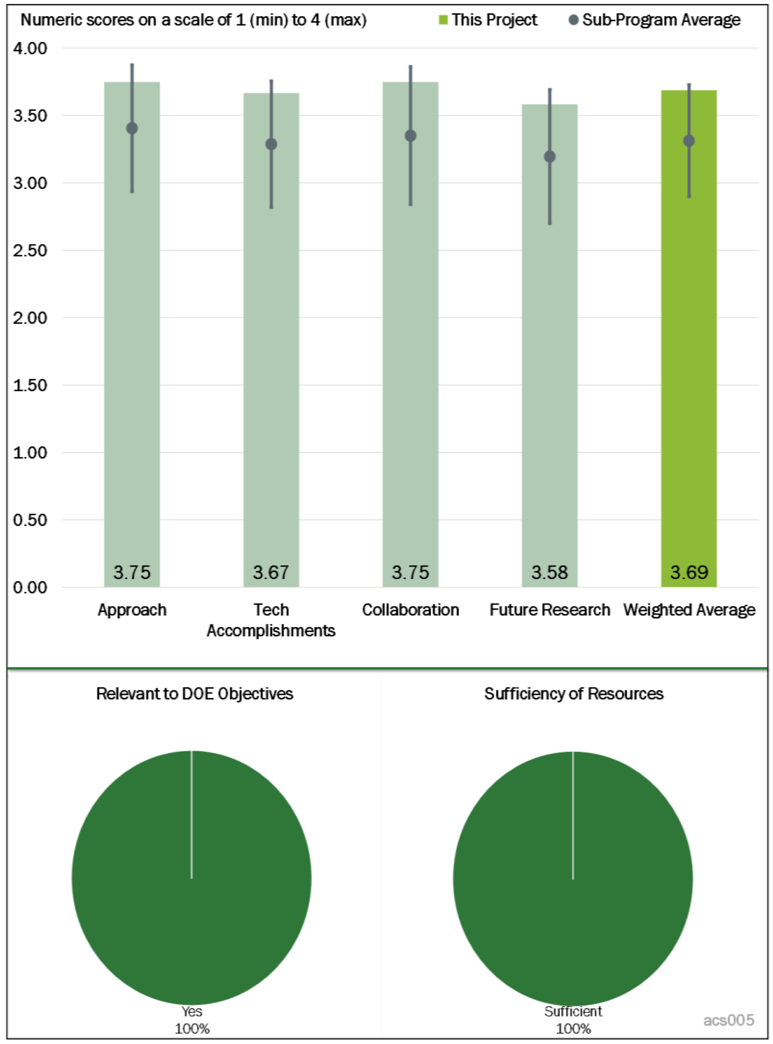

Figure 1-4 - Presentation Number: acs005 Presentation Title: Spray Combustion Cross-Cut Engine Research Principal Investigator: Lyle Pickett (Sandia National Laboratories)

Presenter
Lyle Pickett, Sandia National Laboratories

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer found the approach to this work is excellent as exemplified by the success of the ECN. Clear experimentation and simulation techniques have been brought together to advance the project goal of allowing the development of predictive computational tools for industry.

Reviewer 2:
The reviewer’s opinion is that this is a great program. It is a coordinated effort to advance our understanding and improve our simulation accuracies and fidelity along with experimental accuracies and protocols through the international collaboration of all interested stakeholders. This project appears to be working well.

Reviewer 3:
The reviewer commented the project team has developed and applied different diagnostics techniques to characterize the spray and flame. Some techniques have shown great success, or potential, in revealing the fundamental mechanisms of the spray combustion. For the unsuccessful ones, the project team has honestly addressed the limitation and disadvantages, which is also a good contribution to the community. For soot formation in GDI engine-like condition, the spray injection event makes the process much more complicated. The reviewer said that the project team may consider use a pool of liquid fuel to mimic the wall film, which will ease both measurement and simulation. The project may highlight some successful stories about comparison between experiments and simulations, and/or the impacts of the present project on model developments and validations.

Reviewer 4:
The reviewer found the project to be well-designed and well-planned.

Reviewer 5:

Using advanced spray diagnostics in a high-pressure, fixed-volume vessel allows detailed information to be gathered on gasoline, diesel, etc. fuels in an environment much less complex than an engine cylinder with a moving piston, complex charge motion, etc. The reviewer comments that this allows many technical barriers to higher-efficiency, lower-emission IC engines to be carefully studied and provides much useful data for spray and combustion model development, calibration, and validation for multi-dimensional engine simulation tools that industry needs to design future combustion systems and injectors.

Reviewer 6:

The plot box on the top right side of Slide 10 is singularly dark blue and the reviewer questioned whether this is accurate. The reviewer was unclear which fuel was used for the results shown on Slides 9, 10, 16, 17, 19, and 20.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Significant accomplishments in many areas continue to be made that offer significant progress to achieving overall project goals of more efficient and, in particular, cleaner engines. The reviewer commented that it would perhaps be useful to incorporate some parallel CFD-based research to assist in interpreting and rounding out the information gathered in the experimental work, similar to the approach now being used in the optical engine research at the same laboratory.

Reviewer 2:

The reviewer believed this project is very productive. For measuring techniques, the project team has developed high-speed imaging extinction diagnostic for quantitative measurement of spray mixture and multiple wavelength extinction measurements for soot refractive index study. The project team has applied particle image velocimetry to GDI multi-injection spray, and soot extinction imaging to soot emission near wall film. The team has investigated several engineering problems, including spray and combustion behavior of fuel for engine testing (AVL-18a) diesel surrogates, soot formation near GDI injector, mixing in transient spray, soot formation in pyrolyzing spray, and multiple injection.

Reviewer 3:

The reviewer remarked the technical accomplishments of this program in FY 2018 look to be moving very well. The new mixture quantification absorption diagnostic looks very interesting and may be a key output for other institutions to enact. The work on wall films and sooting looks to be going well also. The reviewer found the presentation to be a bit unclear about the pyrolysis experiments and how to interpret their meaning with respect to the wall films. The reviewer expressed certainty that more time would allow sufficient detailed understanding. This project has been invaluable over the years to OEMs needing to understand and leverage spray diagnostic capabilities. The reviewer also encouraged continued strong support of this project and to consider increasing budget and scope.

Reviewer 4:

The reviewer stated that the results are very insightful as to what fundamental understandings are inadequate and need enhancement before higher fidelity simulations can be developed.

Reviewer 5:

The reviewer said that the team carefully performed a series of tests to evaluate various laser diagnostics techniques and obtained useful guidelines. The reviewer commented, however, the conclusions on the difficulty of the Rayleigh scattering were previously reported in literature. For the quantitative mixing measurement, fullerene molecule used as a conductor (C70) seems to be a promising dopant, but the team needs a careful comparison for distillation matching.

Reviewer 6:
The reviewer found Slide 22 to be clearly stated.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer could only describe collaboration from this project as outstanding. The reviewer stated that the ECN has proven to be a great success due to this project and the collaborative leadership. Furthermore, continued collaboration with industry is highly valuable as well.

Reviewer 2:
The reviewer indicated that one of the outstanding success stories of the entire DOE VTO is the ECN created and managed through this project, particularly in the area of GDI experimental and analytical research collaboration. The reviewer noted, of course, it would be beneficial to the diesel OEMs to see more work done on the diesel side. Additionally, the reviewer noted that there are certainly plenty of problems to consider, particularly in the area of spray/soot relationships. In this context, a greater collaboration with the same national laboratory's optical engine program might generate even more interesting results.

Reviewer 3:
The reviewer found this to be a great collaborative effort.

Reviewer 4:
The reviewer commented that ECN covers the majority of research groups in characterization and simulation of spray combustion in this world. Efficient collaborations have been achieved through the ECN monthly meeting, whose attendees include not only the ECN research groups but also engineers from industry. Per the reviewer, the groups honestly compare their measured and simulated results. The published ECN data have been extensively used to validate spray and combustion models. Such crowdsourcing collaborations have significantly advanced the progress of spray combustion research. The ECN has set up a very successful model for international research collaboration.

Reviewer 5:
The reviewer noted that the ECN has very good collaborations. The ECN partners participate and are well-coordinated.

Reviewer 6:
The reviewer recommended clarifying who does what during collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the new "high-throughput" facility will be exciting, particularly if it lives up to its name by allowing more data to be gathered even more quickly. The overall future research plan proposed is excellent but of course, more is always better, so hopefully future reports will show even more results in more areas. To reiterate a previous comment, particularly in the area of diesel research.

Reviewer 2:
The reviewer remarked that Slide 21 is clearly written.

Reviewer 3:

To the reviewer, the team has identified the most-appropriate challenges to pursue in the ongoing work. The reviewer agreed with the focus of the project's future work.

Reviewer 4:

The reviewer said that the project team has identified soot emission and flash boiling as the major topics for gasoline engines, internal flow, droplet behavior under supercritical conditions, mixing, and ignition for diesel engines. The reviewer considered all of these topics of great importance for industry. For soot emission in gasoline engine, the research plan needs improvements. The current configuration does mimic the engine conditions, but it becomes quite complicated due to the injected spray and consequent wall impingement events. The reviewer said that a simpler and better controlled configuration is required to isolate part of the factors influencing the whole process.

Reviewer 5:

The reviewer remarked the future FY 2019 work seems to be in a very good position. The reviewer recommended considering engagement with the ECN community and OEMs for specific guidance. The reviewer did not see any discussion of decision points, which may be helpful along the way. Specifically, as the new vessel is brought online, there may be opportunities to leverage the new capability to best accelerate or increase the scope.

Reviewer 6:

The reviewer commented that the plan seems effective.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said this project greatly supports the DOE objectives. Great advances in engine combustion understanding and predictive capability have come about from this project and the ECN. This is one of the top DOE funded experimental combustion-spray projects.

Reviewer 2:

The reviewer commented that certainly the research conducted under this program has had, and promises to continue to have, a major impact on reducing emissions from future IC engines. The direct connection between spray research and engine efficiency is a little harder to gauge, so more work perhaps is needed to envision experiments that might highlight this connection better.

Reviewer 3:

The reviewer said that this project improves the understanding of soot formation and the wall impingement.

Reviewer 4:

Per the reviewer, spray characters significantly influence combustion performance of both SI and direct-injection (DI) engines including efficiency, emissions, engine knock, and combustion stability. The whole industry suffers from lack of predictive CFD tools. The present project characterizes the spray and resulting flame under engine-like conditions using advanced measuring techniques, which generates high-fidelity data for model validation. The reviewer said that the project aims to provide fundamental understanding of the relevant physical processes in modern diesel and gasoline engines. The outcomes of the project also have the potential to be applied to other liquid fueled combustion system.

Reviewer 5:

The reviewer believed that this project fits in the DOE goal.

Reviewer 6:

The reviewer referenced prior comments.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that the team has access to the world's top facilities to characterize the spray and flame. The ECN groups include top research groups in measuring and simulating spray combustion. With this good relationship with industry, the team has access to injectors from leading manufacturers including Bosch and Delphi.

Reviewer 2:
The reviewer stated that the resources appear to be adequate for the proposed research.

Reviewer 3:
The reviewer commented that the project team has sufficient recourse.

Reviewer 4:
The reviewer remarked that it seems that the funding level is adequate.

Reviewer 5:
The reviewer stated that it looks okay but the reviewer does not feel to be in an adequate position to judge this.

Reviewer 6:
The reviewer indicated that the project seems to have sufficient resources. However, the reviewer has concern with the new high output vessel coming online in FY 2019. If this funding is coming from Co-Optima, then this may be okay, but the personnel aspect may still be of concern.

Presentation Number: acs006
Presentation Title: Gasoline Combustion Fundamentals
Principal Investigator: Isaac Ekoto (Sandia National Laboratories)

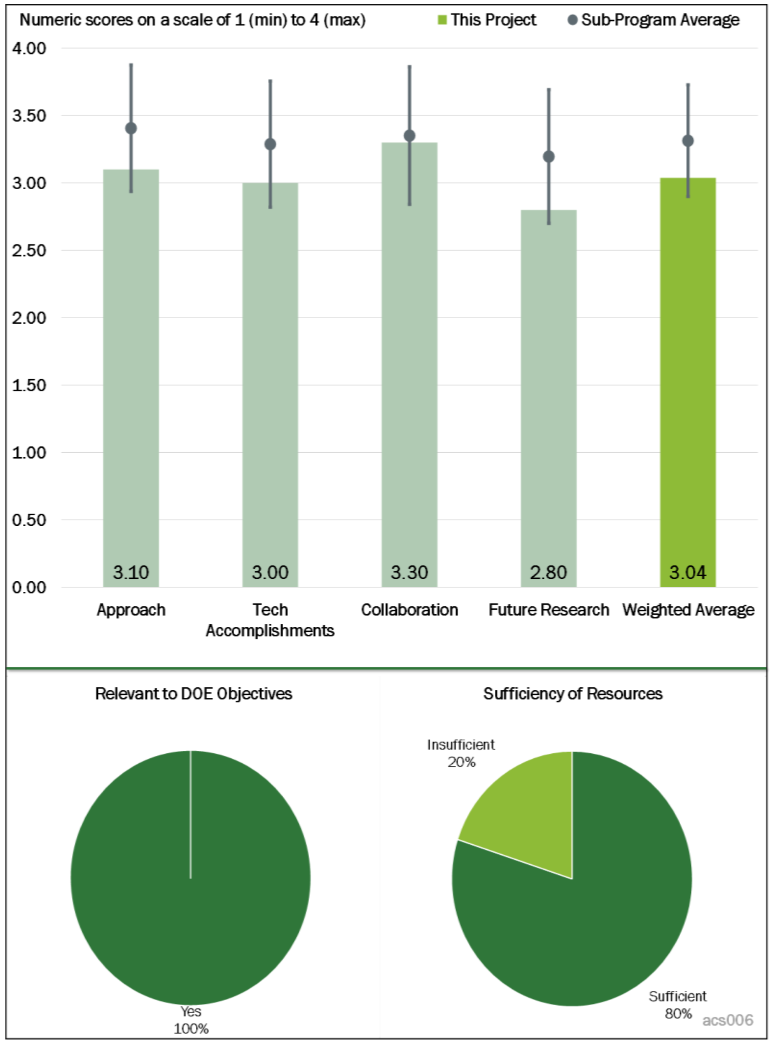

Figure 1-5 - Presentation Number: acs006 Presentation Title: Gasoline Combustion Fundamentals Principal Investigator: Isaac Ekoto (Sandia National Laboratories)

Presenter

Isaac Ekoto, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found that the fundamental measurements and studies to understand the impact of ozone generation on ignition processes to be very good. This can have wide application to in-cylinder processes as well as, potentially, for aftertreatment in certain operating modes. The reviewer believed that this area of study should be extended to evaluate the impact of ozone generation on conventional SI conditions, conventional CI conditions, and to ozone generation from more conventional ignition systems where the ozone yield is smaller but still of interest. For the reviewer, the effort to investigate transient plasma ignition (TPI) in the engine is also of interest. The reviewer would like to see analysis/discussion of the suitability of the test engine to the system as there has been some evidence in the past that high compression ratio small bore engines can be challenging for generation of the plasma rather than arcing due to the small path length available between metal surfaces.

The reviewer has concerns with the current approach for the turbulent jet ignition (TJI) studies. While it is admirable to simplify the system to something that can be probed more easily with experimental tools, the proposed TJI system has significant differences with any of the currently developed production-intent or full production systems. It is not clear to the reviewer that there will be any validation the system at the CRF will be relevant to either a Mahle-style active system or to the passive pre-chamber systems available from a number of suppliers. It would be more productive to ensure that the test system was relevant and included some approach to understand the mechanisms that typically preclude use of the systems such as scavenging, fouling, and heat loss. The reviewer stated that fundamental investigations in this space would assist industry in pushing the state of the art, while investigations on a wholly different kind of pre-chamber system may not produce high-value results.

The reviewer would also like to see some comparison back to conventional ignition systems; a lack of fundamental understanding of TPI and TJI has not been the main barrier to adoption. The reviewer pointed out that cost, performance, and durability have proven to be difficult challenges even without a fundamental understanding. To that end, it would be productive to consider how more conventional ignition system technology compares to these advanced systems and what aspects of the physics of conventional ignition match or do not match those of the more advanced systems. This would provide a bridge for industry to make use of the wide body of knowledge on conventional systems towards the understanding and development of advanced systems.

Reviewer 2:

The reviewer commented that work on transient plasma discharge ignition system is very interesting and must definitely be pursued due to the increased importance of lean burn technologies for high-efficiency engines. The work on TJI is being pursued by industry for both gasoline and natural gas engines and it is not clear what will be achieved in the current project, apart from fundamental understanding. This reviewer felt that the work on plasma is very relevant and important for future engine development, but work on TJI can be downscoped.

Reviewer 3:

The reviewer appreciated the broad range of ignition studies and states these are, in general, useful to further understanding of ignition processes. However, it is not clear how the proposed TJI study is going to help make better engines.

Reviewer 4:

The reviewer said that the approach was shown clearly and encompasses a broad range. While all areas have importance, it would be nice to see more emphasis or results from engine tests to help quantify the potential impact of various igniter technologies.

Reviewer 5:

The reviewer suggested that the team identify a few relevant experiments that can aid in understanding of an advanced ignition system that can enable various combustion modes. Seems like a lot of effort is being spent on understanding fundamentals without having some idea of the potential benefit of the ignition system.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented the ozone studies have shown good progress, with results which are both significant and aid the understanding of the physics of the TPI system. The reviewer found that the development of the diagnostics and use of the calorimeter appears to have required a pretty significant effort, with results that are showing value. The engine results and planning for the evaluation of the TPI and TJI systems do not appear to have made as much progress and the current plans do not appear to align as well with the project goals and especially the needs of industry. The reviewer is concerned that the progress measure may not look as good next year based on the current plans.

Reviewer 2:

The new optical diagnostics to measure oxygen (O_2) concentration that have been developed were very interesting to this reviewer and help with understanding the behavior of the transient plasma ignitor. However, the reviewer was unclear how this information will be used to help improve the ignitor or make a better engine.

Reviewer 3:

The reviewer said that both the quantity and depth of work is impressive. The reviewer would like to see more interpretation/conclusions to assess relative potential of various paths.

Reviewer 4:

The reviewer commented that the team should design experiments to quickly understand the potential of ozone to control CA50.

Reviewer 5:

The progress on the work has been satisfactory. However, the extension of lean limit was unclear from the presentation. The reviewer questioned whether the work can be extended to include high exhaust gas recirculation (EGR) dilution conditions. Improvements on the electrodes to eliminate early arcs and consistent plasma formation are impressive. The reviewer believed that because the work on TJI has not commenced, it is perhaps worthwhile to downscope the TJI work and to re-scope the effort for a broader assessment of plasma ignition system: air dilution, EGR dilution, applicability to multi-mode combustion and integration with dynamic skip fire (DSF), and durability and mechanisms of failure of plasma ignition systems. One of this reviewer's concerns is the presence of the cathode in the piston. The reviewer asked because pistons experience high temperatures, how durable is the cathode. The reviewer also pointed out what if there is soot accumulation at the cathode and how it impacts the ignition system.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found this to be effective collaboration. It is unclear on the value for retrofitting to allow CD. This seems like it would only change boundary conditions, such as trapped residual, slightly.

Reviewer 2:

The reviewer commented that this project has good collaborations.

Reviewer 3:

Per the reviewer, very good collaboration exists with several industry partners.

Reviewer 4:

The reviewer said that the team's collaboration has been really good with industry partners. If both VTO and SNL continue efforts on TJI, then the reviewer recommended including Mahle and Robert Bosch/Michigan State University as collaborators. Both Mahle and Bosch have different approaches to TJI.

Reviewer 5:

The reviewer said there appears to be good and productive collaboration with ANL on the modeling of the TPI system. The reviewer is surprised that there is no collaboration with Esgee Technologies though. Esgee's work, presented at Society of Automotive Engineers (SAE) World Congress, appears to be well-aligned with the effort in this project, and leveraging commercial tools as well as advanced model development within the DOE system seems like it would be valuable.

The reviewer is concerned that there is not enough formal collaboration with ignition system suppliers; Woodward, Denso, and others make passive pre-chambers, and Mahle has been talking about the active pre-chamber system for years. Some more formal collaborations with these companies would help to focus the work within the project to ensure relevance with industry needs.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that the TJI direction sounds reasonable, but more detail would be useful to understand focus. The reviewer questioned which various geometries are to be assessed.

Reviewer 2:

The reviewer referenced prior comments, and expressed uncertainty that the plans for TPI or TJI truly get at what industry needs to be able to develop systems which could be considered for production. The reviewer said there is a large hole in the plans for actually demonstrating the improvement in engine performance and efficiency enabled by these systems, including showing that the energy required to run the systems is more than paid for with the improved performance/efficiency. If that basic metric cannot be achieved, then the rest of the work is not all that useful. The reviewer has not seen enough independent results to date that convinces the reviewer that these systems will enable combustion system developments that move the bar far enough compared to other options available at lower cost/complexity.

Reviewer 3:

The reviewer stated that experiments should be conducted to understand how the pre-chamber cavity is scavenged. Traditionally, not being able to scavenge the pre-chamber has been one of the most significant barriers to pre-chamber ignition technology.

Reviewer 4:

The reviewer commented that future proposed work (except for the TJI work) looks really good. The synergy of plasma ignition system and DSF is extremely interesting and the team should definitely pursue this.

Reviewer 5:

The reviewer opined that the proposed detailed work on pre-chambers may not contribute to improved engine performance. The reviewer commented that the proposed geometry is not relevant and it is not clear what questions will be answered. This work will not address the known barriers to pre-chamber implementation such as scavenging in a running engine, deposits in the pre-chamber, durability of the nozzle holes, heat loss from the pre-chamber, and cold starting performance.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer found this work to be very critical, particularly at this juncture, as more and more lean combustion systems will be put into the market in the future for enabling high-efficiency engines. Various alternative ignition systems have been proposed in the past and none of them have made it to the mass market. This project can enable the penetration of plasma ignition systems into the mass market in the future. The reviewer considered this very timely work.

Reviewer 2:

The reviewer stated that this project provides knowledge base for advanced LTC or mixed mode combustion systems across a broad range. The reviewer considered that this could be key for efficiency and emissions of future combustion systems.

Reviewer 3:

The reviewer commented that this work, to understand the ignition process, is relevant for engine designers to improve future engines.

Reviewer 4:

This project advances the state of the art in ignition technology needed for dilute, lean, and LTC combustion. The reviewer stated that all of these have potential in increasing engine fuel efficiency and reducing petroleum usage.

Reviewer 5:

The reviewer remarked this project does support the DOE objectives for enabling LTC and lean dilute SI combustion. But the reviewer questioned how well the project supports those objectives, particularly with respect to how easily industry could make use of the results.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer suggested a sharper focus for 2018 on TJI and one other system, unless further funding is available. The reviewer considers effort on CD a distraction.

Reviewer 2:

The reviewer remarked the budget and resources appear to be adequate for producing useful results. The reviewer stated that there needs to be a refocusing of some of the effort and for the project team to bring in additional industry collaborations that will ensure the relevance of the results generated.

Reviewer 3:

The reviewer found the project adequate relative to the resources for the project to achieve the stated milestones in a timely fashion.

Reviewer 4:

The reviewer questioned whether resources can be better utilized if each concept is serially investigated with an eye for providing more impactful information to industry, such as completing TPI before getting into TJI.

Reviewer 5:

The reviewer commented that FY 2018 funding of $920,000 seems sufficient. However, the reviewer would like to see that future work is well-aligned with resources as the project is accelerating more experimental work. In that regard, the reviewer would like to see milestones revisited for relevance.

Presentation Number: acs010
Presentation Title: Fuel Injection and Spray Research Using X-Ray Diagnostics
Principal Investigator: Christopher Powell (Argonne National Laboratory)

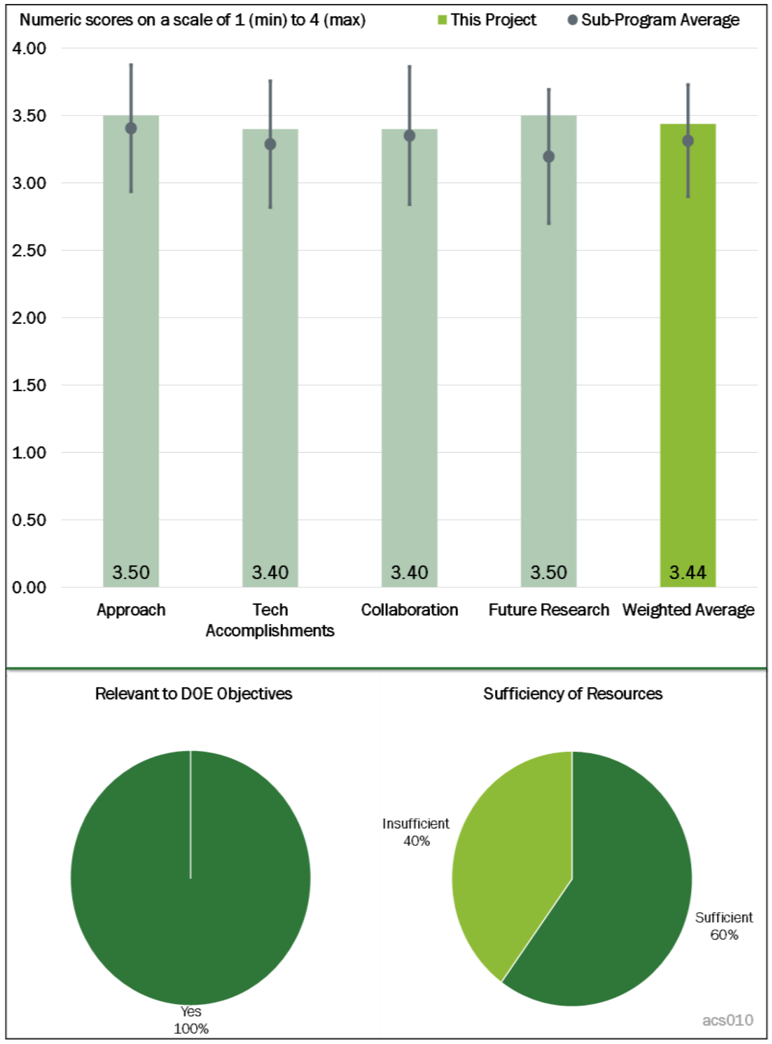

Figure 1-6 - Presentation Number: acs010 Presentation Title: Fuel Injection and Spray Research Using X-Ray Diagnostics Principal Investigator: Christopher Powell (Argonne National Laboratory)

Presenter

Christopher Powell, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the approach to this work is good. Acquiring high-quality quantitative data that is then quickly shared with the combustion and spray community is excellent. This is demonstrated by the high use of this project’s data as reference and validation in the computational literature.

Reviewer 2:

The reviewer found that the approach outlined in the presentation is good. In particular, the investigation into flash boiling is interesting and will be good for further comparison with simulation and other experiments within the ECN. The X-ray diagnostic provides unique data that adds value to the overall understanding of fuel sprays. It appeared to the reviewer that an improvement may be adding a simultaneous diagnostic that can image the fuel vapor, so that a more thorough characterization of spray processes can be done in these tests. However, that may not be physically possible at the X-ray beamline.

Reviewer 3:

The reviewer found that this project continues to supply important near injector fuel behavior quantitative data that otherwise is experimentally difficult to obtain. It is providing important cavitation quantitative and qualitative data for further understanding near injection spray behavior and understanding the influence of nozzle finishing on the aforementioned cavitation phenomenon. The reviewer said that if it has not been addressed to date, two possible suggestions for widening the approach are first, to include wider varying injection pressure and nozzle design experimental work; and second, explore possible multiple-hole nozzle experiments to explore spray to spray effects.

Reviewer 4:
The reviewer commented that the project is well-designed and well-planned.

Reviewer 5:
The reviewer considered the approach clear. However, a project plan would be helpful.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The progress and accomplishments on this project are strong, also indicated by the heavy use of this project's data in the ECN and spray communities. The reviewer stated that nowhere else can near-nozzle sprays be imaged with sufficient quantitative quality and the linking of the near-nozzle spray behavior to internal flow is invaluable. The link between diesel nozzle geometry, flow, cavitation, and near nozzle spray is very clear and can easily help industry justify actions to change physical hardware geometry. The reviewer was not entirely clear how close the experimental conditions were to engine conditions. Any attempts to align injector and ambient pressure and temperature with engine boundary conditions would likely be very valuable, as many times spray and injector behavior change. The progress on the diesel injector and sprays seems to be more mature than the GDI sprays. The reviewer was unclear how much progress was made on the GDI sprays relative to the objectives for FY 2018.

Reviewer 2:
The reviewer said that the technical accomplishments are good and have provided some unique and valuable data. The fact that the project focuses on processes occurring both inside and outside the injector provides additional insight, and this work should continue. The reviewer recommended the project team should be clearer about providing uncertainties of their measurements in future presentations. The reviewer commented that this was requested during the question period and is an important part of reporting quantitative results, particularly from such a complicated technique. Also, it would be good to know what the detection "floor" is for this technique, particularly in the case of flash boiling where there may be regions with very disperse and/or small droplets.

Reviewer 3:
The reviewer found that the use small-angle X-ray scattering method to measure the near-nozzle surface area provides useful information because traditionally quantitative information near-nozzle is very difficult to obtain due to the denseness of the spray. However, it could be even more useful if the surface area can be converted into droplet size distribution as claimed in the milestone accomplishment.

Reviewer 4:
The reviewer pointed out that much work was completed within the last year for both flash boiling exploration effects and in comparing sharp and rounded edge entry nozzles. The reviewer suggested further studying fuel injection pressure and nozzle opening period effects on that latter nozzle study.

Reviewer 5:
The reviewer found Slide 19 to be clear. A possible improvement could be calling it "Technical Accomplishments."

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer found Slide 15 to be clear.

Reviewer 2:

The reviewer found that collaboration on this project can be represented as excellent by the active involvement with ECN, industry, and computational researchers. Everyone wants APS spray and injector experimental data for relevant spray, cavitation, and combustion work. This project is one of the top DOE funded combustion-spray projects and has direct and long-lasting impact to engine and fuel system OEMs. Please continue strong support and resource commitment to this work.

Reviewer 3:

The reviewer noted that flash boiling spray for GDI is of great interest, especially the multicomponent fuel effects on the flash boiling process have not been systematically studied in the past. There are a few groups within ECN currently performing flash boiling experiments using different diagnostics tools. A better collaboration and coordination will be very beneficial.

Reviewer 4:

The reviewer said that coordination with the ECN and teams doing simulation is adequate. It would be good to see more substantial collaboration on two fronts. First, the collaboration with neutron imaging at ORNL was only briefly mentioned, despite the neutron and X-ray diagnostics being important counterparts. Second, and more importantly, the collaboration with ANL’s work on modeling injector degradation through cavitation (S. Som’s work) should be strengthened, particularly as the simulations begin to identify the physics of injector degradation. Comparing the experimental data with the results of simulation will be critical, and hopefully the flow of information does not just go one way, and that a back-and-forth collaboration can be established in order to parse out the controlling physics. The reviewer highly encouraged collaboration with industry on this issue.

Reviewer 5:

The reviewer commented that this project has excellent collaboration including, most importantly, linkage to the engine combustion network.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked the future work proposed by this project is outstanding. Specifically, cavitation erosion is a real barrier to fuel injector designs and operation that can increase engine efficiency and reduce emissions. This is greatly aligned to the needs of HD OEM and fuel system manufacturers. Gaining these erosion data would again be invaluable in conjunction with the flow cavitation data. Also, moving toward understanding real injector variation through used samples of many injectors is a very good step at helping to engineer the real variation. The reviewer commented that the inability of the near-nozzle diagnostic to measure wide-angle, multi-hole diesel fuel injectors is an area that could be investigated further. Alignment to real in-engine injectors and boundary conditions would produce yet another level of achievement and relevance, because this is commonly what OEMs need to be able to predict with computations.

Reviewer 2:

The reviewer said the proposed future work is also promising, particularly the work on near-nozzle fuel density and spray breakup. This is an area where this diagnostic provides unique data and insight. The reviewer suggested that the project team should continue to seek out these unique contributions, not just providing geometries for simulation and data for comparison to simulation. The insights gained into spray break-up in their past work have been very important, and so the reviewer encouraged the project team to continue looking for fundamental questions to answer, in collaboration with both academic and industry partners, where these unique data can be transformational.

Reviewer 3:
The reviewer said that the future work list is quite exhaustive. The reviewer suggested ensuring future nozzle comparison experiments include widely varying injection pressure and nozzle opening period time effects.

Reviewer 4:
The reviewer considered Slide 18 to be clear.

Reviewer 5:
The reviewer commented that the plan seems effective.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
According to this reviewer, the insight gained into spray processes from this unique diagnostics is extremely relevant to DOE goals regarding fuel sprays and advanced combustion modes.

Reviewer 2:
The reviewer commented this is truly a basic research tool that supports other research teams that are working on better understanding the role of near-spray flowfield on emissions formation and engine performance. The reviewer said that it is wonderful to see after nearly 20 years of the onset of this proposed facility and the struggles to validate this tool that it is consistently available to aid the community in better understanding spray behavior of DI diesels and DI gasoline engines during the last decade or so.

Reviewer 3:
The reviewer stated that this project clearly supports the DOE objectives because it enables science-based understanding of injection systems and sprays that are fundamental to engine efficiency and emissions reduction.

Reviewer 4:
Per the reviewer, spray characterization by X-ray is relevant to the DOE and this industry.

Reviewer 5:
The project provides valuable data for DOE national laboratories, industries, and universities.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Considering how valuable this project is to enabling high-efficiency and low emissions combustion systems, the reviewer stated the belief that the resources and funding level in FY 2018 are insufficient. This project could easily be increased in scope and funding to allow acceleration of the value. The reviewer recommends considering increasing funding to allow the project to push towards work in as-close-as possible engine boundary conditions, and the described future work.

Reviewer 2:
For this reviewer, the reduced spending rate in FY 2018 is concerning, particularly given the uniqueness of this facility. The reviewer commented that the funding levels should be maintained in order to continue the valuable work being done by this team.

Reviewer 3:
The reviewer stated that the project team has sufficient resources.

Reviewer 4:

The reviewer stated that it looks okay, but the reviewer does not believe to be in an adequate position to judge this.

Reviewer 5:

The reviewer had no comments.

Presentation Number: acs011
Presentation Title: Advances in High-Efficiency Gasoline Compression Ignition
Principal Investigator: Steve Ciatti (Argonne National Laboratory)

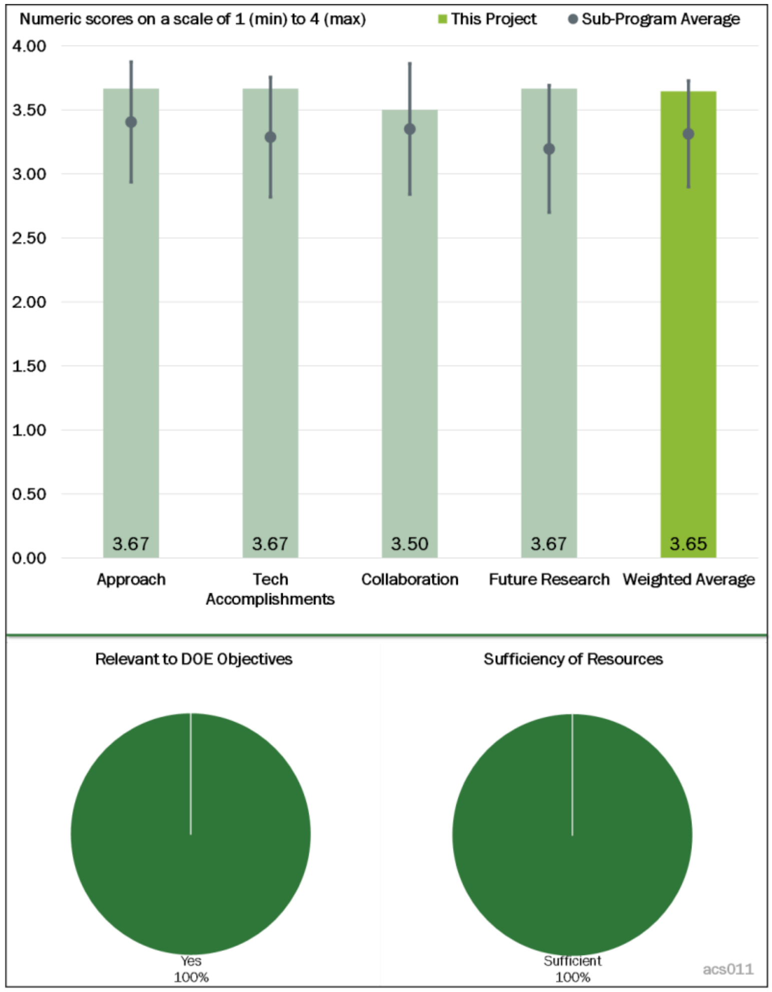

Figure 1-7 - Presentation Number: acs011 Presentation Title: Advances in High-Efficiency Gasoline Compression Ignition Principal Investigator: Steve Ciatti (Argonne National Laboratory)

Presenter
Chris Kolodziej, Argonne National Laboratory

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
It appeared to the reviewer that the researchers had a well thought-out approach to the research allowing solutions to the problems limiting gasoline compression ignition (GCI) engines. The researchers have made great strides in the research toward these goals.

Reviewer 2:
The reviewer commented that the approach could be improved by including a summary of noise and control factors. There is a need to identify noise factors that have significant impact on controlling combustion phasing. Variability in fuel quality also being a potential issue. The reviewer questioned whether the approach will need to employ combustion pressure feedback or if the intent is to identify an open loop calibration approach. The reviewer noted that transitioning from LD to HD is appropriate considering the guidance from the ACEC.

Reviewer 3:
The reviewer found this approach to be clear and relevant.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said accomplishments of this project are excellent. The researcher has shown the ability to achieve high levels of engine efficiency with low combustion noise and low emissions. The approach to achieving these high levels of efficiency is laid out clearly and is achieved over a broad range of speeds and loads.

Reviewer 2:
The reviewer found that the project has made reasonable progress, considering the transition in the project team and issues with equipment damage.

Reviewer 3:
The reviewer commented that the accomplishments are clear.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that the project appears to be ramping up collaborations with HD OEMs.

Reviewer 2:
This reviewer noted that this project has an excellent level of inter-lab collaboration and industry collaboration. Although, it has less academic collaboration.

Reviewer 3:
The reviewer stated that the collaboration is clear.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented with the LD OEM's push for multimode combustion engines, the move to HD research is timely. The reviewer said that the multimode combustion will not need nearly as much research and because the research has already been performed across a broad range of speeds and loads, this research will be beneficial to the HD industry, which is looking for a full engine map solution to their problems.

Reviewer 2:
The reviewer said that GCI at high load is very interesting. The reviewer recommended the project team consider using more ethanol, up to 85% ethanol blend with gasoline (E85), if possible.

Reviewer 3:
The reviewer considered the transition to HD is appropriate.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer remarked this project is a novel approach to improving the fuel efficiency while lowering the engine emissions of HD engines.

Reviewer 2:
The reviewer commented that GCI at high load is important to improve IC engine efficiency in the real world.

Reviewer 3:
The reviewer stated that it supports objectives if barriers are overcome.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that it looks okay but the reviewer does not believe to be in an adequate position to judge this.

Reviewer 2:

The reviewer said this project has sufficient funds for research at ANL. However, to the reviewer it appeared that the project's funds will not allow for collaboration with outside universities or national laboratories.

Reviewer 3:

The reviewer considered this project's resources to be sufficient.

Presentation Number: acs012
Presentation Title: Model Development and Analysis of Clean and Efficient Engine Combustion
Principal Investigator: Russell Whitesides (Lawrence Livermore National Laboratory)

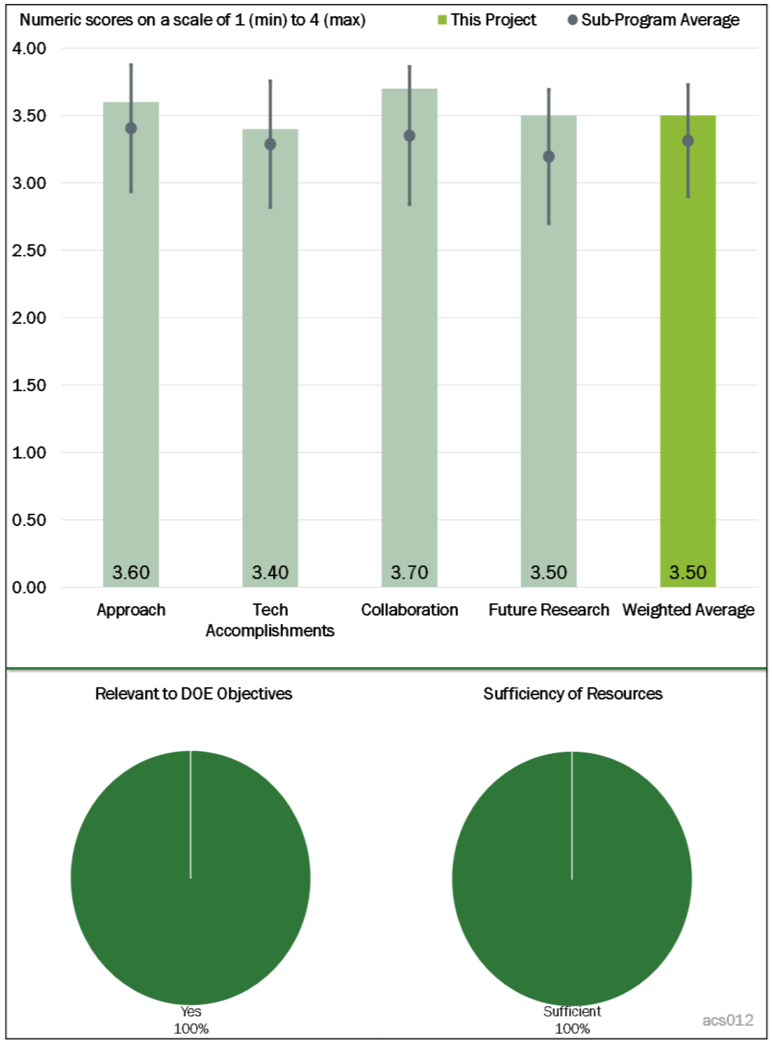

Figure 1-8 - Presentation Number: acs012 Presentation Title: Model Development and Analysis of Clean and Efficient Engine Combustion Principal Investigator: Russell Whitesides (Lawrence Livermore National Laboratory)

Presenter

Russell Whitesides, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that this laminar flamelet approach provides a conceptually useful way to understand the turbulent flame structure in the combustion chamber of an engine. The reviewer commented that this should provide both a useful way to understand the combustion for a range of combustion types, and allow the transition between different types of turbulent combustion.

The reviewer also said that the numeric technology shown here is very impressive. It takes a difficult-to-use turbulent flame model and makes it accessible. Including turbulent diffusion in the laminar flame calculation is great. The reviewer pointed out that in the past, it was not really possible. What is typically viewed as wrinkled turbulent flames should be best treated by this approach. The reviewer suspected that thick flame brush turbulent flame fronts will probably cause major increases in the computational demand. Finally, in spite of all the positives, the computational demands for this technology are significant. The reviewer is not sure any of the OEMs can or will have access to this level of computing resource.

Reviewer 2:

The reviewer remarked the project team is doing a great job in having the approaches aligned well with the barriers. One point is that it may be nice to have an open platform CFD code to implement and test those improvements. The reviewer pointed out that commercial codes are often not appropriate for use in academia.

Reviewer 3:

The reviewer stated that CFD with the detailed kinetics is important for the future high-fidelity engine combustion modeling; however, the detailed combustion mechanism also significantly increases the computational cost. Due to the sparse nature of the kinetics matrix, great potential exists to accelerate the calculation. The reviewer stated that improving the solver is critical.

According to the reviewer, the project team could also consider other approaches to accelerate computational speed. For example, reducing the reaction mechanism on the fly, while keeping sufficient accuracy. The laminar flame speed solver will facilitate researchers to validate reaction mechanisms.

Reviewer 4:
The reviewer found that this is very good work being pursued by LLNL and that it is very timely. Advanced and efficient computation of chemistry and combustion calculations is extremely important for full-geometry CFD simulations.

Reviewer 5:
The reviewer would appreciate more details and examples on transfer to industry CFD toolsets.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said that the technical accomplishments and the progress in the project are excellent. Zero-order reaction kinetics (Zero-RK) and mechanical checker availability to the larger research community is crucial. The plot of computation time for computations with SAGE and Zero-RK with CVODE solver and Zero-RK with SEULEX solver are extremely encouraging. The reviewer said that the laminar flame speed match with experimental data is very encouraging. The project team has performed very well.

Reviewer 2:
The reviewer stated that comparisons with engine measurements (Slides 14 and 15) are evidence that the approach has predictive value.

Reviewer 3:
The reviewer appreciated the work on laminar flame speed, especially as could be used towards knocking behavior.

Reviewer 4:
Per the reviewer, good progress has been made in accelerating detailed kinetics in engine CFD, modeling ECN spray, and predicting laminar flame speed.

Reviewer 5:
There appeared to the reviewer to be solid progress overall. The reviewer suggested that it would be great to see how accuracy compares over solvers (i.e., SAGE to CVODE to SEULEX) in Slide 9. Also, it would be nice to see the measured heat release rate (HRR) and engine-out emission values in Slide 14.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer considered this an excellent collaboration with national laboratories, OEM, and industry.

Reviewer 2:
The reviewer commented that the collaboration list makes an excellent stream starting from fundamentals to end user applications.

Reviewer 3:
The reviewer said that collaboration with groups ranging from computing hardware and software to engine measurements is very encouraging. The reviewer commented that there really was not time to evaluate how close those collaborations actually are.

Reviewer 4:
The reviewer pointed out that collaboration across team members has been crucial to the success so far. The reviewer suggested collaborating with OEMs other than GM. Also, the reviewer questioned whether there is a plan to integrate the Zero-RK chemistry solver with CONVERGE CFD or other CFD software that are used in industry. The reviewer said this will magnify the project's impact.

Reviewer 5:
The reviewer noted broad collaboration. However, the project presentation could elaborate how it was useful (changed focus or accelerated progress).

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said the focus on improving the computational speed addresses what the reviewer views as the primary barrier to applying this technology to the development and application of advanced combustion strategies.

Reviewer 2:
The reviewer commented the future work on data science/machine learning to optimize solver performance is very nice. The reviewer suggested that the project team should also investigate machine learning methods for adaptive chemistry mechanism reduction, if possible. The reviewer pointed out this work will mitigate some of the issues that have been plaguing CFD simulations, e.g., full cycle and full mesh CFD simulations with detailed multi-component fuel chemistry (and PAH chemistry for soot model predictions) can be enabled with these methods.

Reviewer 3:
The reviewer commented that the future research plan does not seem very concrete. Perhaps it is due to the merge of the program. It is going to be nice if a way to evaluate the performance of the new developments out of CONVERGE platform is laid out.

Reviewer 4:
The reviewer liked the idea of conducting more research on uncertainty quantification and sensitivity analysis. The presentation lacked the details of how to combine machine learning for solver optimization. The reviewer is looking forward to learning more next year.

Reviewer 5:
The reviewer questioned what a significant increase in funding would allow.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer found that, yes, the project is well-aligned with DOE objectives. All the development will directly serve the community to better understand and develop advanced combustion systems.

Reviewer 2:
Per the reviewer, this work is very relevant to the DOE objectives and is very timely in nature. The progress of the project team is very impressive.

Reviewer 3:
The reviewer said that the capacity to predict the time dependent flame structure and the instantaneous emissions will dramatically assist in the development of the optimum low-emission combustion technologies.

Reviewer 4:
The reviewer commented that faster, higher fidelity models, with transfer to industry toolsets, have a direct path to lower carbon dioxide (CO_2).

Reviewer 5:
The reviewer remarked that high-fidelity chemical kinetics modeling is critical for future advanced ICE development. The reviewer stated that this project supports the DOE objectives of reducing fuel consumption.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
According to the reviewer, the project team has sufficient resources to achieve the stated milestone.

Reviewer 2:
The reviewer commented that the resources do seem sufficient.

Reviewer 3:
The reviewer said that the FY 2018 funding of $600,000 is very reasonable for modeling/simulation work.

Reviewer 4:
The reviewer stated that there is no evidence that this work is funding limited.

Reviewer 5:
The reviewer questioned what amount of funding is for central processing unit (CPU) access.

Presentation Number: acs013
Presentation Title: Chemical Kinetic Models for Advanced Engine Combustion
Principal Investigator: Bill Pitz (Lawrence Livermore National Laboratory)

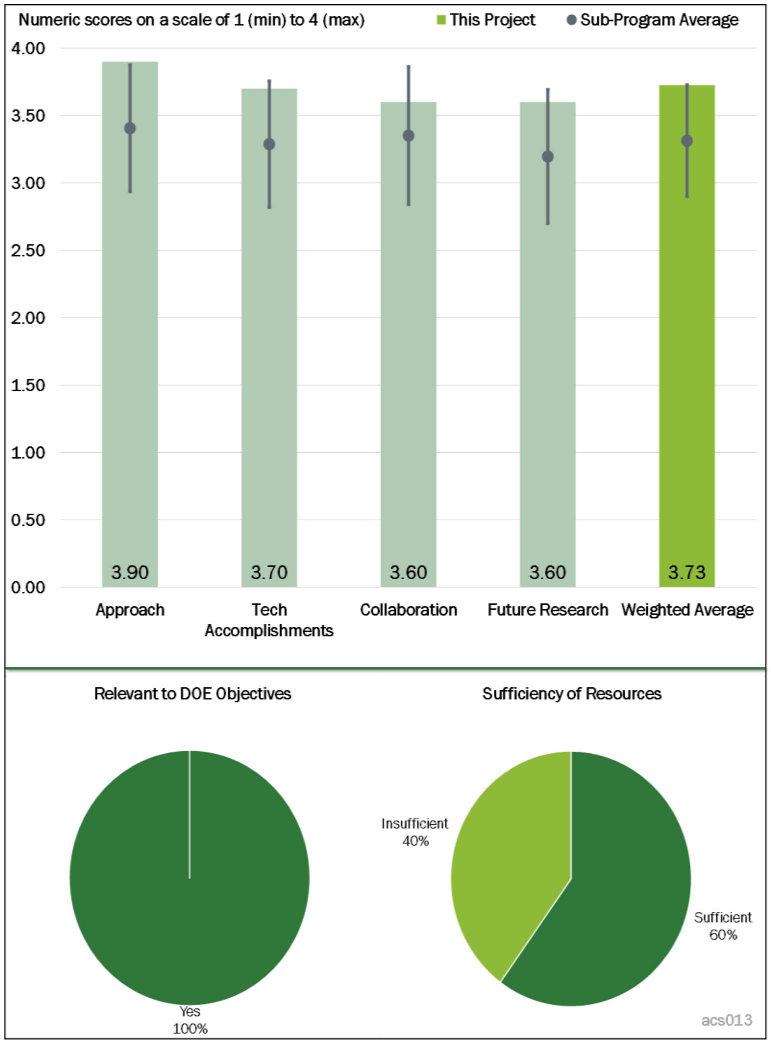

Figure 1-9 - Presentation Number: acs013 Presentation Title: Chemical Kinetic Models for Advanced Engine Combustion Principal Investigator: Bill Pitz (Lawrence Livermore National Laboratory)

Presenter

Bill Pitz, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer pointed out how detailed fuel chemical kinetic models are the foundation for developing advanced engines. The models developed by the project team have been widely used by OEMs, research institutes, and universities across the world for combustion simulation. The team is also making significant progress in improving and adding models every year. The reviewer stated that the project is very well-designed and feasible.

Reviewer 2:

The reviewer found this project has quality research as usual. It is good to focus on developing mechanisms for accurately representing dilute combustion (i.e., EGR).

Reviewer 3:

The reviewer said that the project team completed project milestones. The kinetic models developed or improved in this project addressed the technical barriers on engine efficiency and emissions. The project is well-designed and fit extremely well with the other efforts in the VTO programs.

Reviewer 4:

The reviewer stated that this study represents the only means to approach engine performance barriers from a fundamental point of view.

Reviewer 5:

The reviewer said that the objectives of this project are to develop kinetic models for gasoline, diesel, and next-generation fuels including those mixed with ethanol (which is widely used). The project team has pursued this line of work for a long time and is expert in this field. In the reporting period, the focus was on diesel surrogates and using RCM data as a means to compare predicted and measured results. Additionally, gasoline surrogates are investigated and new surrogate data are reported.

The reviewer remarked that the project is very-well developed and the project team has an excellent grasp of the subject of kinetic mechanism development. The approach this year focuses on gasoline, diesel, and ethanol blends. It develops reduced mechanisms appropriate for CFD simulations and uses the models to predict new data obtained with the project team's collaborators. The reviewer pointed out how many gasoline surrogates have been presented in the past. Here, four and five component surrogates are developed for gasoline and diesel. The reviewer commented that it would be good if the project team could state what differentiates the various surrogates developed in this latest effort from past work on gasoline and diesel surrogates. For example, concerning diesel, Philippe Dagaut and co-workers have proposed a three-component surrogate for diesel (decane/propylbenzene/propylcyclohexane). The reviewer questioned how predictions compare with this (or other) diesel surrogates.

The reviewer pointed out that as the number of surrogate components increases there will be point of diminishing return. The computational difficulties will increase, especially when spray injection is considered. The reviewer questioned whether the project team offers any insights into this potential concern. Ultimately, how the surrogate performs in detailed models of in-cylinder processes is important. Hopefully, future presentations will include such comparisons with those that the project team is collaborating with. The reviewer noted that a significant problem is formation of particulate matter. The project team addresses this by including predictions of PAH mechanisms. The reviewer would like to see any insight about how the kinetics perform when predicting more global features such as soot volume fraction.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said the team made excellent progress on gasoline and surrogate chemical kinetics. The results show that the project is on track to develop kinetic mechanisms that industry and academia can use to improve engine efficiency and emissions. Furthermore, the work on aromatics is very important.

Reviewer 2:
The reviewer said that the team has made significant progress in developing models for key gasoline and diesel surrogate components, and improving aromatic and preliminary PAH mechanisms.

Reviewer 3:
The reviewer remarked the current limitation to this approach is the amount of kinetic data that need to be generated. Ideally there should be a program designed just to generate, first experimentally, then theoretically, the kinetic data necessary to improve kinetic models.

Reviewer 4:
The reviewer commented that progress appears similar to past years and commensurate with funding.

Reviewer 5:
The reviewer pointed out that a range of surrogate components were identified for gasoline surrogates. The results presented gave high-fidelity predictions for pressure versus time in an RCM (Slide 9) compared to RD587 early on, though this was a less satisfactory agreement at a later time. The reviewer questioned whether the disagreement reveals uncertainties in the kinetic rates, rate parameters, properties, the model itself, etc. Similarly, the fuels for advanced combustion engines (FACE) comparison in Slide 10 also show varying degrees of agreement. On the log scale, the difference can be as high as a factor of two. The reviewer questioned what the strategy is for closing the gap, or what the possible reasons are for the differences.

The focus of the problem considered is developing combustion kinetics of complex fuel systems. The reviewer questioned whether there are other inputs to models that could influence predictive performance as well, such as properties (e.g., gas diffusion coefficients), or submodels involved in the simulation (e.g., turbulence), etc. The reviewer also questioned if there is a way to separate these aspects, properties from kinetics that could guide the project team's effort and provide additional guidance on what best to focus on in the development of improved surrogates. The reviewer noted how some comparisons were shown for shock tube data at 220 atm and questioned whether engines operate at such conditions.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said the topic is very complex and it would not work without the excellent collaboration and coordination across the project team. The reviewer found that results of the project confirm that observation.

Reviewer 2:
The reviewer observed excellent collaboration with national laboratories and universities. The reviewer knows the models are also used by OEMs, either directly or in-directly, as they are basically used as benchmarks to develop the reduced mechanisms for engine simulation.

Reviewer 3:
The reviewer remarked the project includes a number of collaborators that are well integrated with the project team's efforts. SNL is a strong choice for engine studies, ANL a strong choice with RCM data, various universities, etc. The reviewer pointed out the good thing about these collaborations is that they provide quantitative interactions and data that the project team needs and uses to advance the work.

Reviewer 4:
The reviewer commented that this collaboration looks solid, and expressed interest in seeing more of the evidence showing how the mechanisms are employed. Perhaps focus on an example as a case study for 2019.

Reviewer 5:
The reviewer suggested that this collaboration should be expanded to include an ignition delays database and modeling from Stanford University.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said future work is well-developed, including more research on surrogates that better represent gasoline, validation, PAH soot models, and more collaborations with the modeler. There is a focus on RCM data. The reviewer also suggested that consideration should also be given to showing data from other combustion configurations. Finally, assessing the various gasoline surrogates would also be useful.

Reviewer 2:
The reviewer said the proposed future work addresses most of the barriers for current fuel or surrogate kinetic models. Future work on aromatics kinetic models is extremely important for correct soot modeling.

Reviewer 3:
The reviewer noted the project is well-planned for future research, especially for PAH soot kinetic model, and reduced versions of gasoline and diesel surrogates for real engine development.

Reviewer 4:
The reviewer recommended a continued focus on dilute combustion SI gasoline.

Reviewer 5:
The reviewer said this study should not only focus on surrogate mixtures. Before moving into complex mixtures, it is necessary to identify the key chemical reactions that control ignition delays, and link the respective chemical reactions to specific fuel molecules.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer considered these data as crucial in simulating engine performance.

Reviewer 2:
The reviewer stated that, yes, from a broad perspective the project does support the overall DOE objectives. Surrogates are the essential ingredients to engine simulation, without which it would not be possible to predict engine performance.

Reviewer 3:
The reviewer said high-fidelity chemical kinetics models are critical for future advanced ICE development. The project supports the DOE objectives of reducing fuel consumption.

Reviewer 4:
The reviewer commented that if the focus remains on dilute combustion, then the project is relevant.

Reviewer 5:
The reviewer pointed out it is difficult to achieve the goals on engine efficiency and emissions without accurate chemical kinetics.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that it is unclear how the project team manages to produce such good results with such a low budget, unless this work benefits from other funding sources as well.

Reviewer 2:
The reviewer said that the project team has sufficient resources to achieve the stated milestone. RCM for diesel surrogate components could be challenging. Also, the reviewer is not sure what data will be used for PAH/soot model validation. The reviewer is looking to learning more about these next year.

Reviewer 3:
The reviewer said there should be a unified program to develop and build this essential database, just like those that exist for stratospheric ozone and climate studies. The reviewer commented that there is not enough knowledge contribution from experts in chemical kinetics.

Reviewer 4:
The reviewer said that the funding appears to be sufficient. Additionally, the project team did not comment on a need for increased funding.

Reviewer 5:
The reviewer stated that resources seem adequate although ultimate judgement would have to come from a cost/benefit analysis based on DOE’s investment relative to the commercialization potential.

Presentation Number: acs015
Presentation Title: Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes
Principal Investigator: Jim Szybist (Oak Ridge National Laboratory)

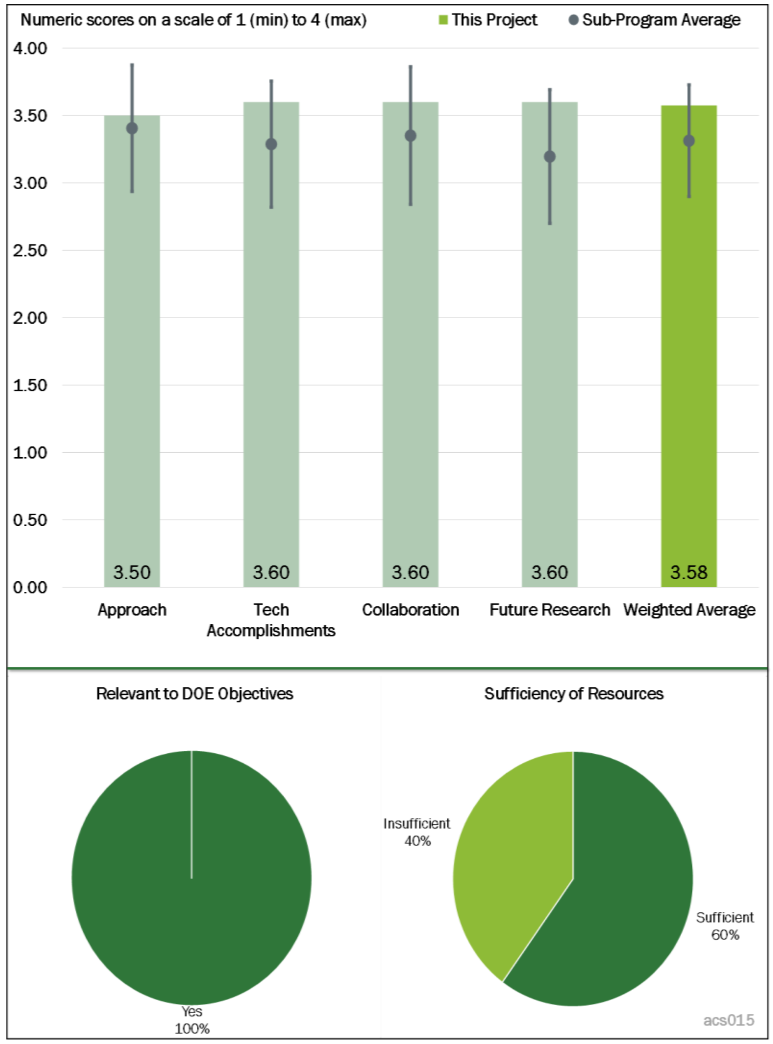

Figure 1-10 - Presentation Number: acs015 Presentation Title: Stretch Efficiency for Combustion Engines: Exploiting New Combustion Regimes Principal Investigator: Jim Szybist (Oak Ridge National Laboratory)

Presenter

Jim Szybist, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer considered thermochemical recuperation an interesting approach which, if successful, is superior to the dedicated EGR approach. The researchers have shown the reasons why this approach gives improvement through thermodynamic analysis. This helps direct the approach they are taking.

Reviewer 2:

The reviewer stated that the project addresses reformation for additional dilution, which is a viable path to higher efficiency. This is a good combination of experiments and fundamentals. The reviewer said additional efforts on practical limitations of concepts would be useful, such as load transient load control, cold start feasibility.

Reviewer 3:

The reviewer noted the approach includes experiments to better characterize catalysts for more efficient reforming. Three areas are targeted: thermal management associated with waste heat recovery through recuperation, incorporate EGR catalytic reforming (that produces syngas) which extends the EGR dilution tolerance, and efforts to simplify emissions control and cost complexity. The effort with cost control was a bit vague and the reviewer is unsure how this will be done.

The reviewer questioned the rationale for selecting the Umicore catalyst with the specifications noted in the presentation—2% Rh supported on aluminum oxide (Al_2O_3) and coated with zirconia-mullite substrate. The reviewer was interested in the rationale to selecting these particular catalyst parameters. The reviewer said the catalyst is incorporated into one cylinder (of a four-cylinder engine). The reviewer questioned whether this cylinder is a sort of sacrificial cylinder from which no power was derived. Also, the reviewer inquired what fuel the team used.

Reviewer 4:

The reviewer said that the project team is investigating manipulating gamma and fuel composition to increase engine efficiency. This is done by thermochemical manipulation of fuel and EGR. The approach using a novel catalyst and a dedicated cylinder for EGR was a unique way to overcome technical barriers to engine efficiency.

Reviewer 5:

The reviewer remarked sound chemical thermodynamic principles are being applied to investigate the viability of this concept.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed very good accomplishments. The analysis accurately delineates the various reasons for the benefits observed. It would be nice to show the amount of exhaust enthalpy being used to heat the catalyst, even though in the current configuration it would be reported as the external energy supplied to the catalyst by the laboratory set-up. The reviewer pointed out the researchers honestly present the challenges they are facing, like S contamination.

Reviewer 2:

The reviewer commented that gamma investigation very high value. More effort needed on catalyst efficiency over time; one hour, 100 hours, 300,000 miles, etc.

Reviewer 3:

The reviewer found that progress has been good considering the practical equipment failure challenges.

Reviewer 4:

The reviewer noted that productivity in the reporting period was excellent with three journal articles published in a prestigious journal. The papers provided details of different fuel compositions, reforming and energy balances, catalyst performance, brake thermal efficiency (BTE) gain, and comparisons with conventional EGR systems. The reviewer said the finding that re-forming with oxygen requires rich conditions is interesting. The units presented on some of the figures were a bit confusing, for example, “fraction of fuel enthalpy” could be better defined. The reviewer said some discussion of being unable to balance the load between cylinders could be useful. The reviewer questioned whether the presence of the thermocouples inside the catalyst has any impact on the measured temperature distribution from the inlet to the outlet of the exhaust.

The reviewer questioned what it is about increasing the RPM that causes the catalyst temperature to increase. In a broader context, it would be useful to do more than present cause and effect in the results but to try to explain what is happening. The effort is one of testing and evaluating, though extracting some physics is useful as well. The reviewer pointed out system modifications were made to enable in-pipe boosted operation. The effort appeared extensive. However, the rationale behind things like increasing the EGR cooler volume, incorporating a bank of flow controllers, and incorporating a rupture disk for more realistic boundary conditions was not clear. The reviewer questioned whether these modifications made on-the-fly or if there more to it, and questioned what caused the equipment failure and what lessons were learned.

The reviewer found that the CHEMKIN simulations on closed cycle thermodynamics for adiabatic conditions were interesting. The geometry of CHEMKIN is very different from the engine environment. The reviewer wondered if the CHEMKIN insights applicable to the present study, and if so why they are applicable. The reviewer also questioned why the project used iso-octane in the simulation and not a PRF (i.e., a mixture of heptane and iso-octane, for example).

Reviewer 5:
The reviewer said that while the project team had several technical accomplishments and showed that the novel approach using dedicated EGR and gamma manipulation had merit (1.5% efficiency improvement), there were several systems limitations that this approach did not account for. The project team does have a plan to overcome these limitations.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that the team is working with a nice mix of interested stakeholders.

Reviewer 2:
The reviewer found this to be good collaboration. The reviewer questioned why, with so many comparisons to similar Southwest Research Institute work (but with key differences), they are listed.

Reviewer 3:
The reviewer remarked the project team had excellent and appropriate partners that they collaborated with.

Reviewer 4:
The reviewer considered that good collaboration exists with industry for its feedback and guidance.

Reviewer 5:
The reviewer said collaborators are appropriate and the collaboration with Umicore is essential. The reviewer questioned whether the project team has plans to collaborate with other catalyst manufacturers. The reviewer commented that it would be good to show closer links with some collaborators. The collaboration with Umicore is clear and the collaboration with the university is very good. OEM collaborations are important, though it was not clear to this reviewer what the OEMs say about the barriers that must be overcome before they will consider implementing the concepts of this project in a product line. The reviewer stated that more specifics would be helpful.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented the project team had a well thought-out plan to overcoming the systems physical limitations. The project team showed what the systems limitations were and how they planned on overcoming them.

Reviewer 2:
Per the reviewer, future work seems to focus on the most salient aspects of the program.

Reviewer 3:
The reviewer stated that all the relevant barriers are being addressed in the future work.

Reviewer 4:
The reviewer said discussion of future work listed activities noted for flow reactor measurements, determining the extent of S deactivation, developing techniques to regenerate catalysts, and 3D modeling. The reviewer commented that the relevance of the one-dimensional modeling could be strengthened.

Reviewer 5:
The reviewer commented that given small funding, proposed future work seems almost too much. The reviewer questioned whether the end game to develop insight and understand catalysts or whether it is to truly commercialize a form of dedicated EGR.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented that yes, certainly the goal of increasing fuel efficiency will be relevant to DOE's interests. In this project, the focus is on the thermodynamics of engine processes and minimization of thermal loss and catalyst performance for reforming.

Reviewer 2:
Per the reviewer, this project is a novel and well thought-out approach to improving engine efficiency while lowering emissions.

Reviewer 3:
The reviewer said improved engine efficiency is targeted, which will reduce petroleum use.

Reviewer 4:
The reviewer stated that this supports the roadmap to LTC.

Reviewer 5:
After listening to the presentation and reading the information in the slides, the reviewer is not so confident that this will be a viable approach to improving efficiency. However, evaluation of this concept is appropriate for a government laboratory. Whether successful or not, valuable learning will take place. The dissemination of the thermodynamic analysis alone represent valuable teaching for the stake-holder community.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
According to the reviewer, resources are only 40%-50% of comparable projects. The reviewer recommended more funding to accelerate research in this area recommended. There is a good track record of efficient spending.

Reviewer 2:
While not stated, it was apparent from the budget size and the technical limitations of the setup that the project team was limited by resources to optimize the approach. The reviewer stated that the researcher has plans to overcome these limitations.

Reviewer 3:
The reviewer commented that resources are sufficient to impact stated goals.

Reviewer 4:
The reviewer said as long as there are not too many experimental problems, the funding seems sufficient.

Reviewer 5:
The reviewer stated that resources seem adequate although ultimate judgement would have to come from a cost/benefit analysis based on DOE's investment relative to the commercialization potential.

Presentation Number: acs017
Presentation Title: Accelerating Predictive Simulation of Internal Combustion Engines (ICEs) with High-Performance Computing (HPC)
Principal Investigator: K. Dean Edwards (Oak Ridge National Laboratory)

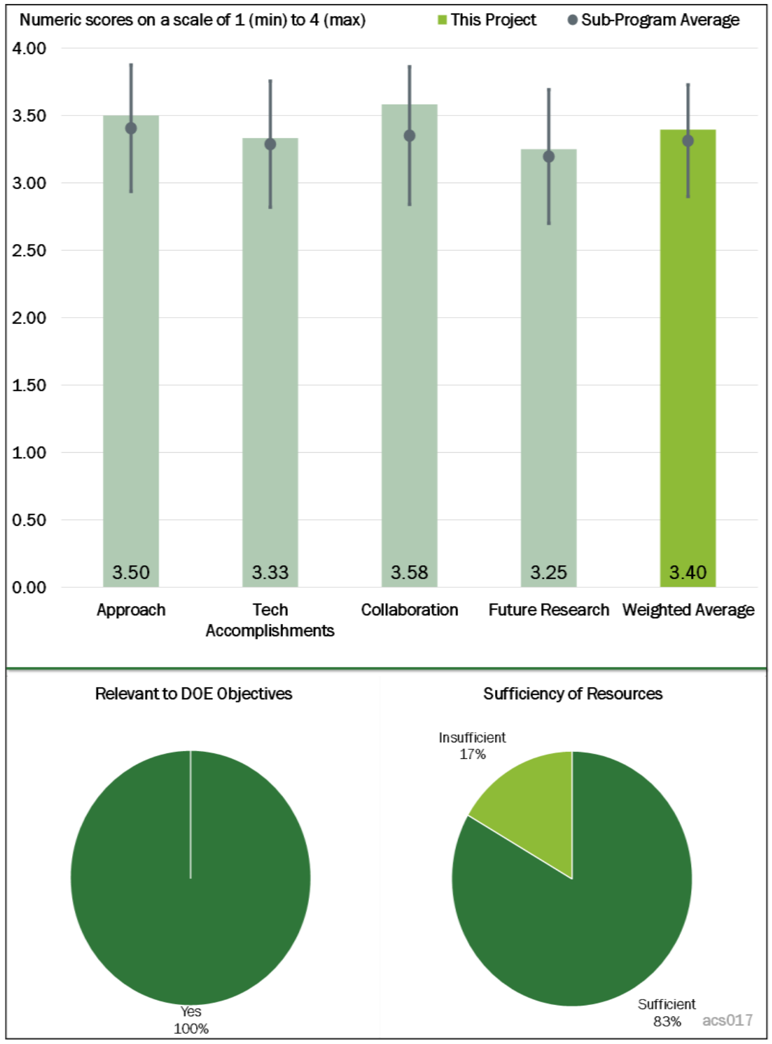

Figure 1-11 - Presentation Number: acs017 Presentation Title: Accelerating Predictive Simulation of Internal Combustion Engines (ICEs) with High-Performance Computing (HPC) Principal Investigator: K. Dean Edwards (Oak Ridge National Laboratory)

Presenter

K. Dean Edwards, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said the approach of working with collaborators to push the limits of HPC by evaluating the computational performance of ever more detailed modeling efforts on realistic industry challenges is excellent.

Reviewer 2:

The reviewer commented that the project team is doing a great job in having the approaches aligned well with the barriers. The reviewer commented that it may be nice to have an open platform CFD code to implement and test those improvements. Commercial codes are often not appropriate for use in academia.

Reviewer 3:

This is an outstanding approach only possible through HPC capabilities at national laboratories. The project is addressing problems relevant to OEMs. The reviewer would like to see what can be done for transient cold start conditions with an eye towards predicting emissions. Assorted sub-models could be combined to predict test procedure emissions. Additionally, a combustion model could be used to establish boundary conditions at the exhaust valve. The reviewer described simulating the exhaust manifold, mixing, heat transfer, and chemistry as the gases move through the exhaust hot end, and turbocharger. Feedgas then enters the catalyst. The reviewer suggested including a catalyst brick model with chemistry to understand how the brick heats up and begins to convert. This entire model could then be used to optimize catalyst heating calibration, exhaust design, turbocharger/wastegate design, and catalyst design on a transient basis. The reviewer is excited to see the possible uses of this approach on full system level transient emissions.

Reviewer 4:

This project shows to industry what is possible by applying HPC to practical problems that industry is facing. HPC addresses the classic tradeoff between speed and accuracy.

Reviewer 5:

The reviewer stated that HPC computing in national laboratories is very important for industry.

Reviewer 6:

The project generally addresses some of the barriers to using HPC to improve combustion system design to reduce emissions and improve efficiency, particularly for smaller engines, especially SI. The reviewer did not see similar scale of effort to address the problems of HDD CI engines. The reviewer stated that more balance between the two would seem to be beneficial since it could be argued that electrification will likely target smaller vehicles first so long-haul, HD power will likely remain combustion-based in the longer term comparatively.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found that the team has pursued and shown success in a broad range of realistic problems such as knock modeling, viral design, LES, and conjugate heat transfer (CHT).

Reviewer 2:

The reviewer stated that this is solid progress overall. The reviewer suggested that it would be great to see how accuracy compares over solvers (SAGE to CVODE to SEULEX) in Slide 9. Also, the reviewer commented that it would be nice to see the measured HRR and engine-out emission values in Slide 14.

Reviewer 3:

The reviewer said that this project is addressing OEM relevant issues.

Reviewer 4:

The reviewer pointed out that knock modelling is being conducted in conjunction with collaboration with Fiat Chrysler Automobiles (FCA). Virtual engine design and calibration is being demonstrated with increased simulation detail and predictive accuracy. This reviewer reported that the effect of increasing detail in chemical kinetic models on predictive accuracy as well as full-cycle simulations and CHT are being evaluated. The reviewer commented that there is still a way to go before emissions can be predicted with reasonable accuracy.

Reviewer 5:

The reviewer said that much of the work parallels capabilities already in place with at least some engine makers or reaching implementation with commercial tools reaching the market. The reviewer commented that the scale of design studies envisioned have already been surpassed by some engine companies as part of routine with automated optimization already in use to offload engineering resources in some areas.

Reviewer 6:

The reviewer found that Slide 4 is clear.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the collaboration list makes an excellent stream starting from fundamentals to end user applications.

Reviewer 2:
The reviewer commented that this is excellent collaboration.

Reviewer 3:
The reviewer said that good collaboration exists with industry, other national laboratories, and CFD software suppliers.

Reviewer 4:
The reviewer commented that Slide 2 is clear.

Reviewer 5:
The reviewer saw collaboration with SI engine makers, but not at the same level for HDD CI engine makers. There is mention of contribution to the SuperTruck II team, but no details are presented as to what is to be accomplished and when.

Reviewer 6:
The reviewer referenced prior comments.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that planned future work seem very much on target. The team will use the code to identify hotspots and autoignition locations. The reviewer questioned whether current capability could be extended to simulating cold start with an aftertreatment system.

Reviewer 2:
The reviewer remarked that proposed work is commensurate with funding. The reviewer would like to see this approach applied to more emissions systems level work for gasoline SI combustion.

Reviewer 3:
The reviewer stated that Slide 19 is good and clear.

Reviewer 4:
The reviewer said the work plan for the future is very good. The reviewer suggested continuing to move towards LES is good.

Reviewer 5:
The reviewer said the future research plan does not seem very concrete. The reviewer found that perhaps it is due to the merge of the program. It is going to be nice if a way to evaluate the performance of the new developments out of CFD software (CONVERGE) platform is laid out.

Reviewer 6:
The reviewer commented that the program does not appear to radically stretch use of HPC-based engine modeling to meet future engine design needs with advanced physical models beyond what industry is already applying.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that yes, the project is well-aligned with DOE objectives. All of the development will directly serve the community to better understand and develop advanced combustion systems.

Reviewer 2:
The reviewer commented that yes, techniques only applicable to HPC at the moment can cascade to industry as computing capabilities progress.

Reviewer 3:
The reviewer remarked robust tools to help with engine design and calibration are very much needed to reduce design cycle times and calibration effort and time.

Reviewer 4:
The reviewer said yes, research appears to be targeting DOE objectives of fostering cleaner and more efficient IC engines.

Reviewer 5:
Per the reviewer, virtual calibration is relevant.

Reviewer 6:
The reviewer said this is the type of work that national laboratories should be doing.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that funding could be increased to support emissions simulations.

Reviewer 2:
The reviewer stated that for what is proposed, the resources appear to be adequate.

Reviewer 3:
Per the reviewer, it seems that the financial resources are sufficient.

Reviewer 4:
The reviewer found that the resource does seem sufficient.

Reviewer 5:
The reviewer considered the resources sufficient to meet the stated goals.

Reviewer 6:
The reviewer does not believe to be in an adequate position to judge this.

Presentation Number: acs022
Presentation Title: Joint Development and Coordination of Emissions Control Data and Models (Cross-cut Lean Exhaust Emissions Reduction Simulations [CLEERS] Analysis and Coordination)
Principal Investigator: Josh Pihl (Oak Ridge National Laboratory)

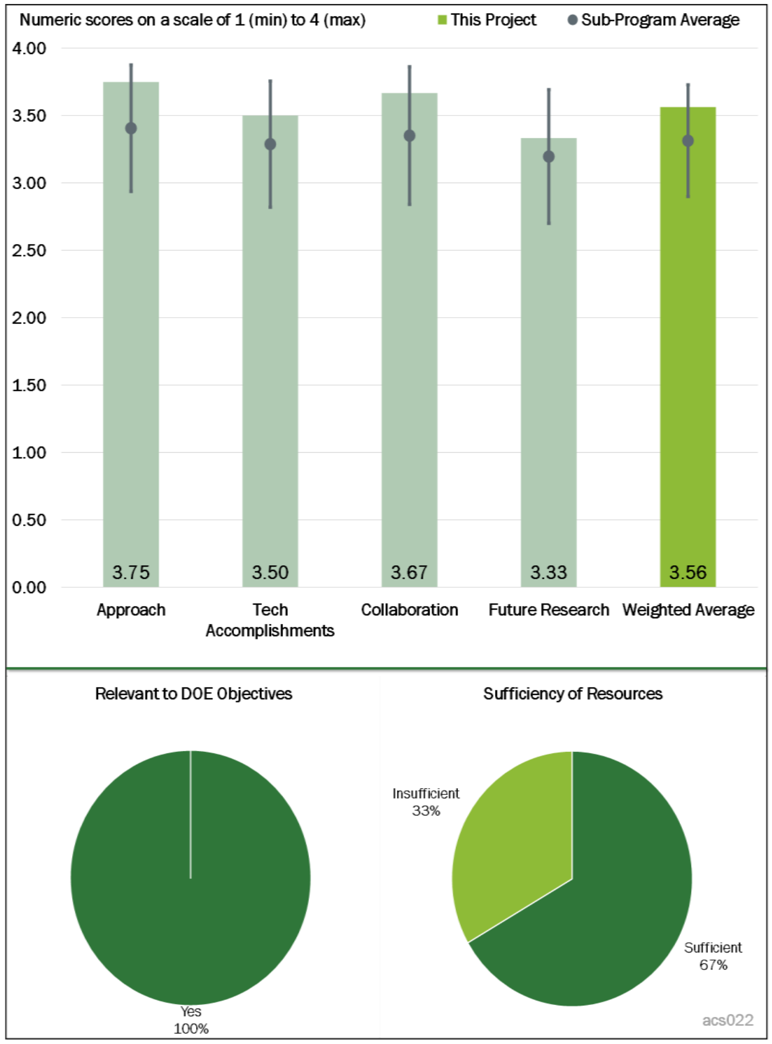

Figure 1-12 - Presentation Number: acs022 Presentation Title: Joint Development and Coordination of Emissions Control Data and Models (Cross-cut Lean Exhaust Emissions Reduction Simulations [CLEERS] Analysis and Coordination) Principal Investigator: Josh Pihl (Oak Ridge National Laboratory)

Presenter

Josh Pihl, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found that given the diverse set of modeling tools used by the stakeholder community, the approach of generating appropriate model inputs (kinetics, etc.) for general use is wholly appropriate. The project seems to have two main purposes operating in parallel. First, coordinating CLEERS, and then conducting the related catalytic converter research that CLEERS prioritizes. Per the reviewer, this approach seems to work, though, because feedback from one part feeds the other.

Reviewer 2:

The reviewer said that CLEERS utilizes a mix of "tools" such as their website, annual workshop, monthly teleconferences, and expert presentations. Additionally, a flexible inclusive policy, developing strong relationships in dealing with the industry, its issues and challenges, the use of modeling, coordination, and dissemination of relevant information, and so on. The reviewer noted that the CLEERS charter has grown from a mere aftertreatment modeling circle (its initial charter a decade and a half ago) to one now also including engine development topics (gasoline, diesel, natural gas) and testing, and has stayed well connected with industry needs and its outlook.

Reviewer 3:

The reviewer stated the CLEERS annual workshops and monthly focus group teleconferences continue to provide an effective forum for sharing results and ideas related to exhaust aftertreatment modeling. The current focus on low-temperature oxidation/storage catalysts as well as catalyst aging mechanisms and multi-functional devices is timely and relevant.

Reviewer 4:

The reviewer pointed out that CLEERS directly addresses barriers called out in the 2018 ACEC Roadmap. Meaning that it is still a relevant and important activity for DOE to fund. This cross-cutting group spans industrial, academic, and national laboratory researchers and encourages the interaction between the groups.

Reviewer 5:

The reviewer remarked CLEERS continues to provide much-needed pre-competitive collaboration by emission researchers from a variety of companies and institutions on multiple emission challenges, including SCR, passive NO_x adsorber (PNA), and low-temperature catalysis. It provides this service by planning and coordinating the annual CLEERS conference, monthly teleconferences, and the semi-annual CLEERS survey. It also is performing technical analysis of catalysts to provide the data needed for computer models of such catalysts.

Reviewer 6:

The reviewer described that the Cross-cut Lean Exhaust Emissions Reduction Simulations (CLEERS) organization supports and promotes the research and development of innovative catalyst technologies by hosting multiple venues. In particular, the annual CLEERS workshop and monthly teleconference serve as excellent forums for disseminating information related to advanced aftertreatment materials and technology directions. Also, through the annual aftertreatment survey, focus areas of research are communicated to the catalysis community. However, care should be taken when interpreting the survey to make sure OEM needs are actually addressed.

The reviewer said that with respect to research efforts conducted by the CLEERS group, the shift in research emphasis to PNAs is consistent with the needs of OEMs to address LTAT. The PNA and selective catalytic reduction (SCR) modeling efforts of this group have been very helpful in characterizing and understanding the behavior of these catalysts in vehicle applications. The reviewer suggested, however, realistic test conditions meant to simulate cold start could be better captured in the characterization conditions, as well as proper aging.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the team has posted on the CLEERS website catalyst test protocols developed by the Low-Temperature Aftertreatment subgroup, and are starting to receive considerable attention from catalyst researchers in academia. Also, the annual CLEERS Workshops continue to attract significant interest, as evidenced by the increasing number of attendees in recent years.

Reviewer 2:

The reviewer said there are several accomplishments of note from the CLEERS activities. First is hosting the annual CLEERS workshop, which is very successful. Second is their contribution to United States Driving Research and Innovation for Vehicle efficiency and Energy (U.S. DRIVE) efforts to develop protocols for characterizing catalysts and accelerating the development of new catalyst materials. Third is their annual survey highlighting catalysis focus areas.

The reviewer pointed out that CLEERS' work in characterizing and developing PNA catalyst materials addressed LTAT needed by OEMs for both lean and stoichiometric exhaust systems. The reviewer commented that progress appears slower than expected and incorporating poisons and proper aging into their test protocols is highly desirable.

Reviewer 3:

The reviewer said that it is still in the early days with the adsorber technologies, but the results seem like they could be promoted more widely, e.g., SAE conferences or publications. The reviewer questioned whether there are more opportunities for joint publications showing how the data from this project are being applied in industry. The reviewer perceived that the CLEERS workshops and other activities are an asset for the broader stakeholder community.

Reviewer 4:

The reviewer detailed how CLEERS is a government sponsored program having created its own benchmark. It has grown from a small circle to one having industry wide impact, even outside the United States. CLEERS monthly teleconferences have become highly educational and stimulating, and its annual workshops have become one of the best interaction opportunities in the “development” circles. The reviewer pointed out that CLEERS’ focus has expanded to include discussions on various combustion, emission, and proper topic diversity (relevance). The reviewer congratulated the ORNL project team for having created such a stimulating circle for information exchange.

The reviewer said that while CLEERS did a good job integrating properly modern gasoline engine developments in its focal discussions, it has been slow in directing sufficient focus from lean NO_x trap to SCR to accommodate the HD diesel industry needs and trends. Nevertheless, in the absence of the still-missing Directions in Engine-Efficiency and Emissions Research (DEER) conference, the value of CLEERS is growing fast. Its absence from the powertrain community would create a major interaction void much needed in today’s quickly changing powertrain atmosphere.

Reviewer 5:

The reviewer noted that the annual workshop and the monthly teleconferences are always well done and well attended. The industry survey is of benefit to lab and university researchers to continue to pursue high priority work. The reviewer noted on the technical results presented in Slides 17-22, because the changes are so small, the reviewer suggested that it would have been really nice to have some idea of the error associated with the measurements. In order to understand how significant the differences are, the reviewer suggested error bars on the bar graphs.

Reviewer 6:

The reviewer said this was a very interesting parametric study on the PNA technology, including the effects of water (H_2O), CO_2, nitric oxide (NO) level, and O_2 level. The reviewer would have liked seeing the effect of S level on the PNA performance as well as the effects of temperature and air/fuel (A/F) ratio during aging. On the effects of O_2, it would have been interesting to look at 0% O_2, to represent stoichiometric operation. For H_2O, the reviewer would have liked to see the range extended down to zero, to see how much the total absence of H_2O improves the oxides of nitrogen (NO_x) storage performance. The reviewer suggested looking at the effect of different hydrocarbons and H_2 on the performance as well.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer pointed out there is excellent collaboration between ORNL, PNNL, the ACEC Technical Team of USCAR, the cross-cut team, universities, etc. The reviewer commented that this project is the poster child for collaborative research.

Reviewer 2:

The reviewer said CLEERS has done an outstanding job in helping develop proper collaborations with the industry, academia and national laboratories. It has indeed gone above and beyond its initial charter, brought “added value” to the industry, and has made a positive, irreversible impact. The project is a model for wide-ranging interactions across various sectors (emissions, engine, light, heavy, etc.).

Reviewer 3:
The reviewer remarked the CLEERS organization has very good collaborative and partnership programs across OEMs, suppliers, universities, and other national laboratories.

Reviewer 4:
The reviewer said the larger groups (ACEC Technical Team, and CLEERS Workshop participants) provide breadth and depth of collaboration. The collaborators do appear to inform the research directions taken.

Reviewer 5:
The reviewer said that the coordination of OEMS, national laboratories, universities, and suppliers is clearly a strength of this activity.

Reviewer 6:
The reviewer noted good and effective collaboration between engine/vehicle manufacturers, universities, and national laboratories. However, the reviewer would like to see more active interaction and engagement with catalyst suppliers.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer pointed out that in general, the project's work continues to support the movement toward high fuel efficiency engines by modeling and characterizing catalyst technologies that enable these engines. In particular, focusing on PNA and SCR technologies that are able to function at low temperatures is extremely important for meeting Tier III emissions standards. The reviewer said that staying closely connected with OEMs and their supplier base will help direct the projects towards appropriate technologies.

Reviewer 2:
The reviewer remarked this project ends in FY 2018, but seems likely to continue. Because the current project seems to have two parts operating in parallel (CLEERS coordination and CLEERS research), the reviewer suggested that perhaps it would be worth considering splitting the two parts into separate projects.

Reviewer 3:
The reviewer remarked CLEERS' research work in aftertreatment has stayed in synch with industry activities, although some other key industry challenges have not been regarded. Examples the reviewer cited include high failure (warranty) rate in HDD emission control components/systems, or algorithm development for urea injection, an area of considerable importance especially with growth in SCR focus as a primary means of NO_x reduction. Having said this, the reviewer also understood that their resources are not infinite as the team may not be able to target all existing needs.

Reviewer 4:
The reviewer commented that this is such a worthy activity because there is an on-going need for coordination and collaboration, especially as we tackle the upcoming problems of gasoline particulate filters (GPF), and low-temperature (LT) aftertreatment.

Reviewer 5:
The reviewer noted that the durability studies on PNAs and hydrocarbon (HC) traps are much needed, including the effects of aging temperature and A/F ratio. The effects of S will be a ripe area for study as well, as well as the ability to desulfate the catalyst.

Reviewer 6:
Per the reviewer, there is perhaps too much focus on aftertreatment technologies (e.g., SCR) for diesel and other lean-burn engines. The reviewer suggested that it might be appropriate to look beyond conventional ICE's, such as hybrids, which may play an important role during the transition to all-electric powertrains.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer remarked, in general, this project team's research efforts are strongly coupled to the desire of OEMs to meet future emissions requirements by employing LT aftertreatment systems. The Also, CLEERS activities are strong, encouraged, and supported.

Reviewer 2:
The reviewer commented CLEERS and the research activities it helps coordinate are supporting DOE objectives for more efficient ICEs. Higher engine efficiency generally means lower exhaust temperatures and a corresponding challenge in emissions control.

Reviewer 3:
The reviewer pointed out this project well supports the overall DOE objectives by focusing on efficient ways to reduce exhaust emissions while at the same time improving fuel efficiency.

Reviewer 4:
The reviewer commented that this project absolutely supports the overall DOE objectives. This is one of the core and key activities of the VTO emissions portfolio.

Reviewer 5:
The reviewer noted the catalysts that are being investigated (PNA, HCT, SCR, LT catalysts, etc.) will be necessary to meet stringent emission standards with the advanced combustion concepts that are being investigated to improve fuel economy. So, all the work supports the DOE objective of reduced fuel consumption.

Reviewer 6:
The reviewer said yes, and by a large margin.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said every year, under the CLEERS umbrella, ORNL (and to some extent PNNL) do a lot of work in coordinating the workshop, teleconferences, newsletters, and surveys. In addition, the team brilliantly leverages the CLEERS funding and insight to advance the knowledge base in specific catalyst areas. In fact, it is common to see previous reviewer questions such as "why aren't you studying XYZ catalyst?" as there are not currently enough resources for ORNL to be actively working in all of the industrially relevant research areas as identified by industry itself in the survey. The reviewer commented that based on the amazing work the team pulls off, the reviewer can only imagine what more they could do with additional funding.

Reviewer 2:
The reviewer found it difficult, as an ORNL outsider, to judge how wide CLEERS' resources are. The reviewer commented that because some of the niche industry needs remain untackled, it is fair to say the team could benefit from more resources.

Reviewer 3:

To this reviewer, it appears that the current levels of resources are sufficient. If similar work expands into the area of HC traps while maintaining the work on PNAs, there might be a need to expand the level of resources.

Reviewer 4:

The reviewer commented that the resources appear to be sufficient. However, funding should be set before the current FY to ensure projects are not delayed.

Reviewer 5:

The reviewer commented this project involves both coordination and support/execution of emission control research. However, it appears that the coordination effort takes up considerable amounts of resources, leaving insufficient resources available for the other part.

Reviewer 6:

The reviewer stated that the resources available seem well-matched to the project objectives.

Presentation Number: acs023
Presentation Title: CLEERS: Aftertreatment Modeling and Analysis
Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

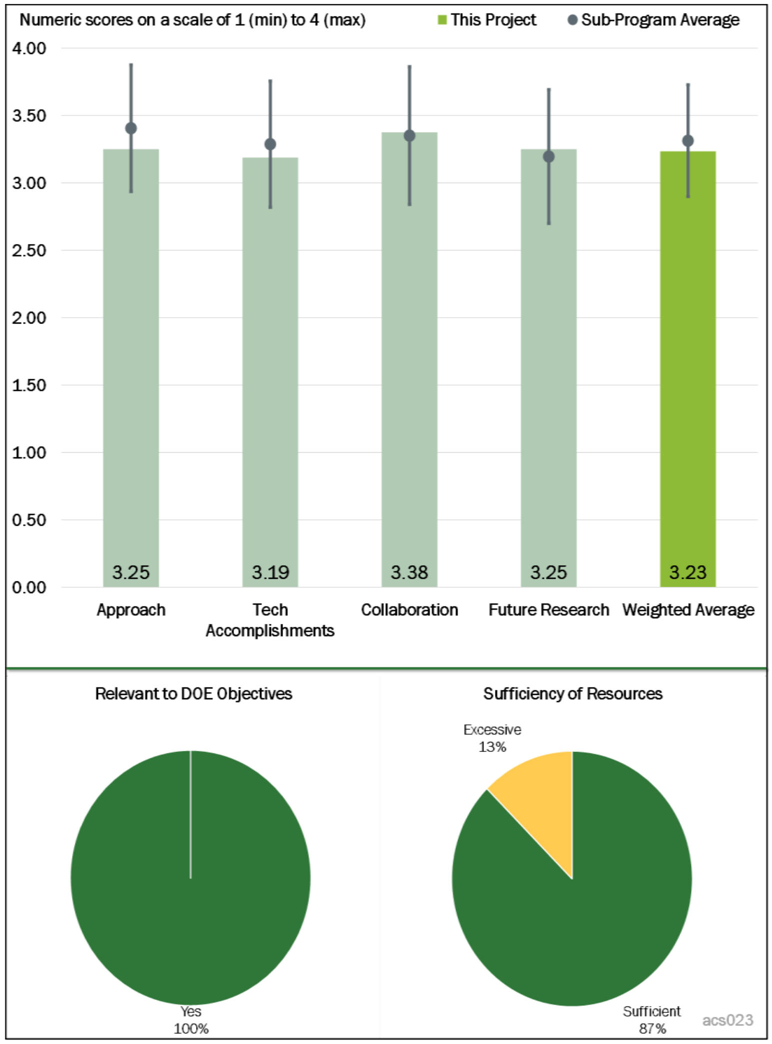

Figure 1-13 - Presentation Number: acs023 Presentation Title: CLEERS: Aftertreatment Modeling and Analysis Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

Presenter

Yong Wang, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of eight reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the range of activities of PNNL's CLEERS work, combined with that of ORNL, makes for a very strong effort to look at areas that have been cited for interest in the survey of industry, a major piece of learning that comes from the survey. A yearly survey could be useful, but the surveyed might not like it. It would be worth finding out. The reviewer noted that part of the approach is also the development of protocols for doing experiments in important areas like storage materials or oxidation catalysts. These are done in interaction with the ACEC group of DOE. These experimental protocols to follow are developed by active practitioners to make it easier, as one goal, for new researchers in that area (e.g., from a university) to achieve results and develop new catalysts that will be relevant and tested sufficiently to be of interest, ultimately, to the companies and laboratories that are using these catalysts. The reviewer said that very visible, but also very important, is the arrangement of approximately monthly presentations to the CLEERS members and collaborators in this project of recent work via a teleconference presentation.

Reviewer 2:

The reviewer commented the PNNL team is focused on fundamentals of several key emission control technologies; SCR, PNA, selective catalytic reduction on filter (SCRF), and LT oxidation. The reviewer pointed out strides are being made in moving SCR activity to lower temperature. This melds nicely with the work on PNA, although, the reviewer was unclear from the project review as to which of the two is more important in meeting the 150° Celsius challenge.

Reviewer 3:
The reviewer stated that this project demonstrates the excellent application of PNNL's expertise in science to study real-world emission problems.

Reviewer 4:
The reviewer commented this program addresses a broad range of technical barriers across multiple technologies. The LTAT catalyst formulation work seems promising if it can be made commercially viable. The reviewer commented that on Slide 9, the legend is missing, and the heat treatment conditions are unclear.

Reviewer 5:
The reviewer said the project has sharpened its focus and resources to tackle the emerging catalytic material challenges from a fundamental perspective in SCR, PNA, and LTAT. The research work pertaining to material characterizations and rational optimizations were particularly thought out, and an extensive collaboration with both academia and industry sees positive outcome. Despite the solid content, the reviewer said that the actual work does not truly echo the project tile of "modeling" from a reaction-engineering point of view.

Reviewer 6:
The reviewer remarked the strategy is appropriate, but the range of partners appears to be somewhat limited and could result in the project being too specifically focused on the commercial needs of one coater/one OEM.

Reviewer 7:
The reviewer noted that CLEERS, by its very name, is simulations focused. The reviewer commented that it is not clear how these PNNL projects support that mission anymore. Over the past several years, we have seen the approach of this project drift away from usefulness. The reviewer said it is clear that ORNL takes the lead on coordination of the website, workshop, and monthly calls. In particular, the reviewer is bothered by the statement on Slide 5 to "utilize CLEERS work to support industry cooperative research and development agreement (CRADA) activities"—which should be supported by their own funds, not CLEERS. It also completely disagrees with the following bullet to "maintain clear separation between CLEERS and CRADA activities."

Reviewer 8:
The reviewer commented that the project is spread too thin. It would be better to stick to two or three topics maximum as opposed to the four chosen here. Also, per the reviewer there should be more emphasis on modeling than was presented here.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said that the technical accomplishments have been excellent. The fundamental understanding gained on SCR (such as electron paramagnetic resonance [EPR] work, alkali addition), PNA, and oxidation (single atom catalysis) has had different impacts. With SCR, the work supports the emerging consensus about copper/chabazite (Cu/CHA); one does wonder if continued work on SCR is justified given that urea is still limited to 180°C minimum operation. The reviewer remarked industry has avoided the ammonia (NH_3) generating solid materials. With PNA, the impact is on understanding the underlying mechanism necessary for modeling. The reviewer pointed out the synergy here with ORNL is critical. With oxidation, the demonstration of LT activity due to high-temperature treatment has potentially very important implications for emission control in general.

Reviewer 2:
The reviewer commented that the technical accomplishments have been met with a large measure of published work (14 papers) with results that are very significant in that area of SCR catalysts and PNA materials in particular, areas of great interest to companies in this field. The reviewer stated that accomplishments are well-

described in the presentation. Other accomplishments also include the protocols developed through interaction with the ACEC group.

Reviewer 3:

The reviewer said it has been claimed that the LT SCR activity was increased with co-cation addition. The reviewer does not think the improvement is significant when compared, for example, with the high-temperature durability. The experiments need to be done at varying space velocities to discern effects of improved kinetics versus improved pore diffusion. The reviewer said that for PNA, it will be useful to develop a mechanism and validate with reactor experiments. For computerized tomography (CT) work, this type of work has been done. The reviewer said the value will be to demonstrate using the wall-scale coating distribution to predict filter-scale performance (pressure drop, filtration, etc.). Even if directionally correct, that will be a big step forward.

Reviewer 4:

The reviewer said that if the PNA and 150°C milestones are met, the program appears to be on schedule. The reviewer commented that there is good alignment between the individual projects and the stated barriers. For instance, the LT performance barrier is addressed in LTAT and SCR work, while the PNA work is focused on underlying mechanisms. The generation of 14 peer reviewed papers as well as the LT test protocol work is impressive.

Reviewer 5:

The reviewer gave kudos to the project team for performing the work writing up the catalyst testing protocols. The reviewer found that identifying different copper species with different hydrothermal aging (HTA) conditions very interesting. Because the project is attempting to improve the LT activity of the SCR catalyst, it would have been nice to have looked at the effects of S poisoning on the co-cation formulations, because S tends to decrease the LT activity of SCR catalysts. The reviewer found the analysis of the PNA technology was excellent. The reviewer questioned whether the effect of CO on the NO_x storage could be consistent with the formation of nitric oxide and carbon monoxide, because 2150 cm^1 corresponds to isocyanate. Very interesting work on the single-atom Pt catalyst. The reviewer commended the project team for looking at the effect of S on its performance.

Reviewer 6:

The reviewer commented that while the quality of analysis is good e.g. for the nature of the Cu species in Cu-CHA, and the interpretation sound, the work does not appear novel. For example, Slide 7 highlights findings known within the field of SCR for several years. In addition, the use of co-cations in Slide 8 is more of an academic artifact. The reviewer said that using co-exchanged Cu and alkali metals would be challenging on a commercial scale, and the project team does not address potential issues arising from high-temperature mobility of alkalis such as solid state reaction and subsequent degradation of cordierite. The PNA characterization and analysis was well-conceived and executed with a solid interpretation.

The reviewer said that the analysis of SCR filter shows coating of an asymmetric cell diesel particulate filter (DPF) and dictates massive maldistribution of washcoat. The reviewer questioned whether this was a commercial SCRF. The reviewer has never seen such an issue on a commercial product. This would result in significant flow by-pass and loss in performance, which the reviewer does not think has been reported in the field. The reviewer remarked the platinum (Pt) 1/cerium oxide (CeO_2) catalyst is an academic artifact. The cost to produce this reproducibly on a commercial scale would likely be prohibitive. In addition, the test protocol does not include any of the known transient poisons, such as heavy hydrocarbons that would delay light-off. It gets headlines but actually detracts from the real challenges in emissions control.

Reviewer 7:

The reviewer remarked the project has made significant progress that largely exceeds the committed expectation from last year's report. The relevance of the fundamental findings in addressing practical challenges is highly visible. However, the reviewer emphasized that the 150°C challenges are far from being solved in terms of both absolute activity (not just showing temperature but absolute turnover rate) and durability, particularly for prevalent gasoline LD vehicle adoptions in the United States.

Reviewer 8:

The reviewer commented that it is nice to see publications resulting from this work, but they seem to be at a fundamental level, below the useful level for supporting device level models, which is the focus of CLEERS. The reviewer was surprised to see the LT protocols called out as accomplishments under PNNL's part of CLEERS as this was a joint effort. The reviewer would like to echo another reviewer's comment from last year that it would be nice to understand what part of this work was used successfully by companies in models, in line with the mission of CLEERS.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented this is a role model that other projects should be measured against.

Reviewer 2:

The reviewer said the range of collaboration and coordination on this project encompasses the entire commercial, national laboratory, and university community doing research and using results in this area.

Reviewer 3:

The reviewer stated there was great collaboration between PNNL and the ACEC Technical Team for developing the catalyst protocols. Collaboration in the areas of SCRs and PNAs was not as obvious.

Reviewer 4:

The reviewer suggested that PNNL needs to more clearly synergize with the ORNL CLEERS project. In particular, PNA is common to both project teams, but it is unclear how the work of both teams will lead to a PNA model. Along these lines, the PNNL team's focus on the fundamentals is laudable. The reviewer said, however, there does not seem to be any effort to develop predictive models. This, after all, is the main objective of CLEERS.

Reviewer 5:

The reviewer suggested that it will be useful to get a catalyzer on-board the team or get their technical inputs.

Reviewer 6:

The reviewer said the team shows a good range of partners, although these are primarily in the academic sector.

Reviewer 7:

The reviewer commented a few of collaborations that exist with CRADA partners seem strong. The reviewer questioned how much PNNL really collaborates with ORNL on coordination of CLEERS as it seems to be solely ORNL.

Reviewer 8:

The reviewer remarked this program seems to create future collaborative efforts (CRADA). The reviewer found the level of collaboration and coordination on the individual projects difficult to judge due to a lack of sufficient information in the presentation slide deck.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that the proposed future work is extensive and guided by the excellent accomplishments thus far. Especially interesting would be the future results to understand the distribution of SCR catalyst material in SCR-filter multi-functional devices. This is especially true, because of the great interest in making more compact systems that still maintain excellent functionality in the exhaust. The reviewer said results here could guide work on both SCR catalysts and filters to make them more capable in this area.

Reviewer 2:

The reviewer stated that the proposed future work follows on logically from current undertakings.

Reviewer 3:

The reviewer commented that the overall proposed future research direction is good, but there should be greater emphasis on coming up with product level models which are validated with transient experiments.

Reviewer 4:

The reviewer remarked the team intends to address a range of challenges pertinent to the industry. The reviewer would recommend including an increased range of industrial partners.

Reviewer 5:

The reviewer suggested that the project team investigate the effect of S on the low-temperature activity of the new SCR catalyst. It would also be interesting to examine the effects of other exhaust species on the performance of the Pd/SSZ-13 PNA catalyst, including hydrocarbons, H_2, CO_2, H_2O, and sulfur dioxide.

Reviewer 6:

The reviewer said that stability of the PNA under DPF regeneration rich spikes has been identified as a major roadblock for the potential application of PNA in the United States. The reviewer suggested that the corresponding anti-deactivation mechanism and approach should be studied with considerable urgency.

Palladium (Pd) and alumina are the workhorse of the low-temperature oxidation catalyst formulation that this project has not addressed. The reviewer said the cross comparison of temperature at which 50% conversion occurs (T50)/temperature at which 90% conversion (T90) (not the absolute activity) in current report slides is not sufficient to exclude other formulations other than the simple Pt/CeO_2, the latter of which is clearly not active for propene (C_3H_6) conversion despite the satisfying CO oxidation activity. The reviewer remarked a continued optimization of formulation and structure is more anticipated before conducting application-oriented durability studies.

Reviewer 7:

The reviewer commented that the focus on fast SCR is questionable, and asked what is to be learned. Standard SCR is slower than “fast” SCR, so it is not clear what the goal is. Moreover, with fast SCR a $NO:NO_2 = 1$ ratio is needed. The reviewer asked from where the NO_2 comes from at temperatures of less than 180°C.

Reviewer 8:

The reviewer said one of the reasons that the future work was not rated higher is because the reviewer lacked confidence that the project team will listen to reviewer comments.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said increasing the efficiency of IC engines is a technologically proven and cost-effective approach to dramatically improving the fuel economy of the nation's fleet of vehicles in the near- to mid-term. This is an overall result of this project, providing its relevance to DOE objectives.

Reviewer 2:
The reviewer commented that yes, it does support overall DOE objectives, as development of models and reaction mechanism will help towards improved catalysts and LT performance.

Reviewer 3:
The reviewer said the work has a sound basis, it has realized some significant milestones towards to DOE goals. There is evidence of significant and meaningful collaborations and some examples of commercially relevant developments.

Reviewer 4:
The reviewer said the project has sharpened its focus and resources to tackle the emerging catalytic material challenges that U.S. vehicle technology needs. The reviewer appreciated the very positive response to last year's reviewer comments.

Reviewer 5:
The reviewer remarked the catalyst technologies the project is investigating are necessary to allow the implementation of advanced engines and combustion concepts that are being developed for reduced fuel consumption while simultaneously meeting strict emission standards.

Reviewer 6:
The reviewer found the topics of inquiry are generally in line with DOE interests.

Reviewer 7:
The reviewer stated that the program is well-aligned with the U.S. DRIVE ACEC Roadmap.

Reviewer 8:
Per the reviewer, this project has obvious relevance to DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said PNNL has excellent facilities to conduct the research.

Reviewer 2:
The reviewer remarked the team is addressing several challenges but are well-funded. Thus, any issue in delivery is not for want of support.

Reviewer 3:
The reviewer commented that the projects appear sufficiently funded.

Reviewer 4:
The reviewer said based on the quality of the results and the large number of collaborators who support this project, its resources appear to be sufficient to the task.

Reviewer 5:
The reviewer stated that it appears the resources are sufficient for this work.

Reviewer 6:
If resources are scarce, the reviewer suggested that the project team focus on fewer areas than the four currently chosen.

Reviewer 7:
The reviewer commented the team has already secured enough resources to achieve the committed goals. The reviewer expected to have a clearer description from the project team regarding how the knowledge generated from this project teaches industry breakthroughs. This is a vague point in current state of the work, and it is hard to justify if the industry resources have been utilized.

Reviewer 8:
The reviewer recommended consolidating the CLEERS program under ORNL and letting PNNL focus solely on their CRADA projects, which seems to be what happens with their CLEERS budget too.

Presentation Number: acs027
Presentation Title: Next-Generation Selective Catalytic Reduction (SCR)-Dosing System Investigation
Principal Investigator: Abhijeet Karkamkar (Pacific Northwest National Laboratory)

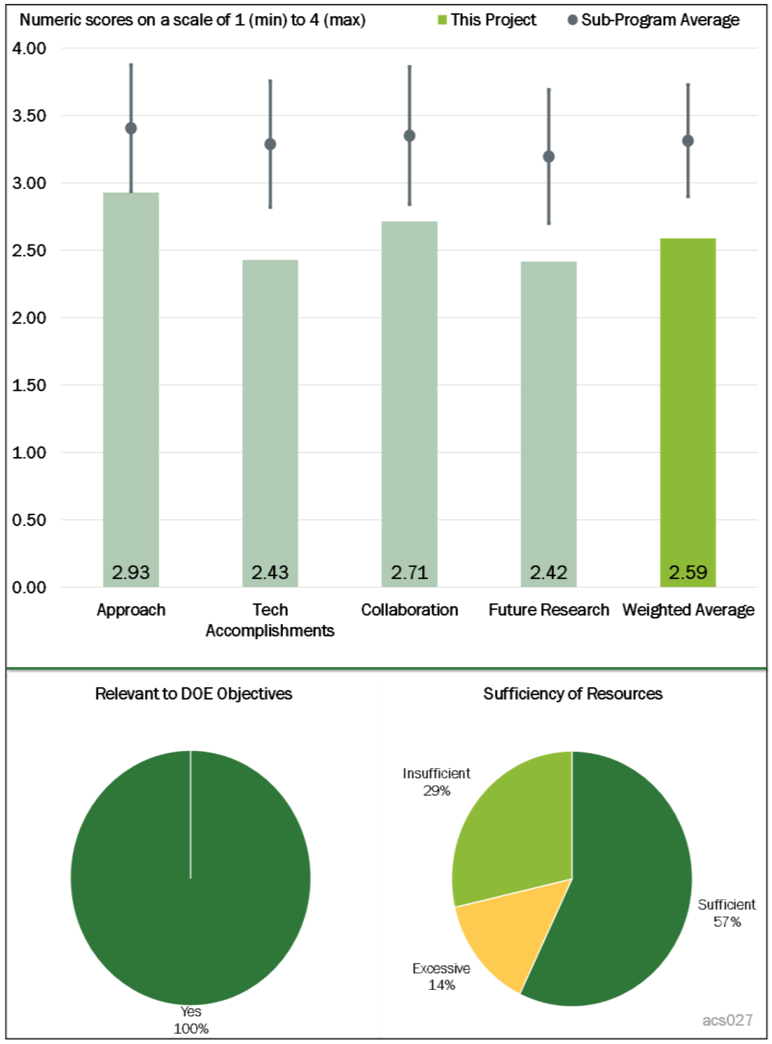

Figure 1-14 - Presentation Number: acs027 Presentation Title: Next-Generation Selective Catalytic Reduction (SCR)-Dosing System Investigation Principal Investigator: Abhijeet Karkamkar (Pacific Northwest National Laboratory)

Presenter

Abhijeet Karkamkar, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer pointed out that because of reviewers' comments in 2017, the goal of the project was made to include materials for NH_3 storage that do not include chlorine (Cl), especially because Cl had been observed as present in the outflow from the solid storage material. A choice was made to look at oxide materials, which would be one way to go. Because there were already materials, like ammonium carbamate, in the list of candidates that did not include Cl, this reviewer would have preferred a shift to understanding the barriers perceived for that material or other non-Cl materials on the list. Although unstated here, the perceived issue there appears to be the reported reformation of ammonium carbamate in cooler areas of a tube or a valve after it is put in the gas phase. Hence, an approach to define the temperatures, concentration/dilution dependence, and "sites" necessary for that reformation would seem to be of importance to see if it could be minimized. The reviewer said that potentially the energy cost of selective removal of CO_2 from the outlet gas from the heated section could be explored (and may have been, based on Slide 14, although not mentioned in summary of results). Such a change in the approach would shift the skill sets included in the project, but these are certainly achievable with the laboratory personnel present.

Reviewer 2:

The reviewer commented the project seeks to identify a suitable replacement to aqueous urea for lower temperature, compact generation of NH_3. This past year the team has focused on finding non-chloride compounds because hydrochloric acid (HCl) generation is to be avoided. That said, as presented it seemed to the reviewer as though there was too much sustained consideration of Cl-containing compounds and not enough consideration of weakly acidic metal oxides. The latter is the target, but per the reviewer the project does not appear to have a systematic as opposed to Edisonian approach. The project would benefit by classifying a class of compounds in terms of their acidity and perhaps include a high throughput screening approach in place to accelerate discovery.

Reviewer 3:

The reviewer commented that the approach is good, but more rapid screening should be undertaken to address the constraint of finding a new non-chloride based material.

Reviewer 4:

The reviewer said that this appears to be a viable downselection process for an alternative NH_3 storage medium for SCR. There is some question of the commercial viability or industry acceptance of transitioning to a new NH_3 storage medium given the pre-existing urea water solution/liquid urea (DEF) infrastructure. Some clarification or comment on the commercial viability would have been very helpful. The reviewer found Slides 15-18 difficult to follow. Additional information such as a legend or description is needed.

Reviewer 5:

This project tackles the practical limitations of NH_3 storage (controlled storage plus volume change) in current urea-based SCR systems for the low-temperature diesel NO_x emission control. The team considered last year's recommendation for the latest work to investigate the impact of Cl release and to search for more material candidates.

Reviewer 6:

The reviewer pointed out that a non-urea source of NH_3 will be necessary to allow NO_x conversion below 180°C, because this is the temperature at which urea decomposes to NH_3. So this project is needed to explore various non-urea sources of NH_3. The reviewer found it commendable that the author listened to feedback and made efforts to minimize Cl emissions, in order to avoid HCl in the exhaust which can cause corrosion problems.

Reviewer 7:

The reviewer said while there were clear statements regarding the challenges related to the current use of DEF and the nature of some of the targets required for replacement of DEF by a solid system, the team did not provide sufficient detail regarding how the solid system would or could be implemented. The reviewer remarked the presentation gave the impression that the project was highly exploratory and academic in nature and had limited connection to real end-users such as washcoater, OEM, and system integrator. Given the advanced state of the project, the reviewer was surprised not to see any demonstration data on an engine dynamometer or a vehicle.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer pointed out that as for progress, the current benefits in chemistry seems to be incremental rather than revolutionary compared with the baseline technology. The project identified several indications of the promising role about the eutectic salts. However, further confirmation and optimization is still under way. The reviewer found the quantified conclusions to be limited.

Reviewer 2:

The reviewer remarked the data presented were of reasonable quality, but was solely laboratory-based and described only model systems. Moreover, in Slide 11, for the comparison of HCl measurements, there was no standard test protocol, which makes comparison of some of the data points challenging. In addition, the temperatures quoted are all significantly higher than the lower temperature challenge window of "urban driving" shown in Slide 22. The reviewer pointed out that in Slide 14, the project team share data on the CO_2 adsorption, another model system. The reviewer questioned why not NH_3 because this is the aim of the project. In Slides 15-18, the team share thermogravimetry/differential scanning calorimetry data for NH_3 loss from another model system. However, this is a one-shot test; the reviewer asked did the team execute repeat cycles of uptake and release or does the team envision the system a one-shot use cartridge versus a rechargeable unit. If the latter, this "disposable" solution would make it a less attractive alternative to DEF.

Reviewer 3:
The reviewer noted that the team has generated some interesting data, but it does not appear the team has selected a final candidate for the storage medium. The reviewer commented that this is the fourth year of this study and the results do not seem to point in a clear direction relative to the goal of the project.

Reviewer 4:
The reviewer said the studies of eutectic and oxide materials provided new information on those as solid NH_3 storage agents. None appeared able to compete effectively with compounds on the existing list. Slide 14 considers CO_2 storage, but appears alone on that topic. The reviewer said that data slides, in general, did not include a take-away message that connected them to other work. The reviewer suggested that, although this project is ending soon, it would be good to pull these results together.

Reviewer 5:
The reviewer remarked progress towards identifying attractive alternatives appears to have stalled. In part this is a result of avoiding metal halides. The project may benefit from bringing in a materials chemistry expert who is versed in molecular computational methods.

Reviewer 6:
The reviewer stated that the progress is rather limited. The project seems to be still far away from identifying a new material which comes close to the desired properties.

Reviewer 7:
The reviewer found it difficult to understand the plots which showed weight loss versus temperature. The reviewer questioned how this shows NH_3 uptake and release. Perhaps the figures need to be explained in more detail in future presentations so the audience can better understand them. The reviewer also found that more explanation of the test procedures would be helpful.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that the collaboration with the USCAR SCR team is most appropriate. Possibly an even broader set of contacts could be employed to get a broader view of the options for this project to consider and follow through on.

Reviewer 2:
The reviewer said that the project has obvious collaboration between USCAR and PNNL. The reviewer stated that PNNL is very responsive to suggestions from USCAR member companies.

Reviewer 3:
The reviewer considered the coordination between PNNL and USCAR adequate.

Reviewer 4:
The reviewer suggested that it may be useful to involve industry to a greater extent to expedite the discovery and testing of new materials as some may already have been explored earlier.

Reviewer 5:
The reviewer stated that the project claimed frequent communications with the USCAR organization and OEM development teams. However, the technical guidance and commitment from the OEM side seems insufficient. The reviewer noted that limited evidence in the report to show obvious engineering and control support from OEMs.

Reviewer 6:
Per the reviewer, there was limited evidence of collaboration demonstrated in either the slides or shared verbally.

Reviewer 7:
The reviewer expressed not seeing much evidence of collaborations with other researchers or other institutions.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that future plans were to continue looking at oxide materials, mentioned on Slide 9. A novel concept for NH_3 adsorption was mentioned on Slide 9, but no results or explanation was given, especially for future research. The reviewer found that there was no actual slide on future plans. The reviewer said that if USCAR continues this project, the comments made on changes in approach would hopefully be considered. Because there was an overlap in the scheduling of the AMR meeting and the meeting of the North American Catalysis Society (NAM 25) in 2017, the reviewer was unable to participate at AMR.

Reviewer 2:
The reviewer commented that the project management seems, in comparison to other projects, somewhat disorganized. The project has laudable objectives, but it seems like a more systematic approach could be taken. For example, molecular-level computations might be a way to accelerate the discovery of new materials.

Reviewer 3:
The reviewer suggested considering non-chloride salts.

Reviewer 4:
The reviewer said no future work has been outlined, probably because the project ends in September.

Reviewer 5:
The reviewer remarked a verbal statement was made in this regard, but only a limited view was shared in the slide deck.

Reviewer 6:
The reviewer said current work appears to continue until project end in September. The reviewer found that no future plans beyond this are apparent.

Reviewer 7:
The reviewer said the project is about 3 months away from completion and it is hard to gain the confidence that an alternative NH_3 carrier material can be sufficiently developed and become ready for SCR dosing study on a system level in that time.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer pointed out that a low-temperature SCR activity is key to improving de-NO_x performance, and such basic research on the topic is important.

Reviewer 2:
The reviewer stated that low-temperature NH_3 dosing for SCR supports fuel-efficiency and emission regulation goals for diesel engines.

Reviewer 3:
The reviewer remarked engines with higher fuel economy will produce lower exhaust temperatures, which will require catalysts that can treat the emissions at those lower temperatures. If SCR catalysts are developed that can provide NO_x conversion at 150°C on diesel engines, there will be a need for NH_3 delivery systems that can provide NH_3 at 150°C without forming deposits on the catalyst. Thus, per the reviewer this project supports DOE’s goal of reduced fuel consumption.

Reviewer 4:
The reviewer said volume-efficient storage and fast release of the stored NH_3 when needed are critically important for fully utilizing the catalytic capability of any given SCR catalysts downstream.

Reviewer 5:
The reviewer stated that a replacement for urea as NH_3 source is critical to reduce the low-temperature hurdle for SCR.

Reviewer 6:
The reviewer said the work is a limited attempt to address a known issue in the field of emissions control. However, the character is highly academic in nature and there is limited substance or end-user specific examples shared by the team.

Reviewer 7:
The reviewer commented clearly, a successful discovery of a material and its usability for solid NH_3 storage would improve fuel economy by using a temperature range where SCR catalysts function, but the NH_3 reductant is not able to be used now because of urea’s relatively high decomposition temperature.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that resources at PNNL are sufficient for this project. The reviewer found that any resources provided by the U.S. DRIVE SCR team were unclear.

Reviewer 2:
The reviewer stated that the resources for this project appear to be sufficient.

Reviewer 3:
The reviewer said the project utilizes capabilities and facilities at PNNL. However, it seemed as if these could be used even more comprehensively.

Reviewer 4:
The reviewer stated given the limited progress made on the topic and considering the ambitious goal, it may be useful to add some more collaborators from industry and expedite the screening process.

Reviewer 5:
The reviewer said given the limited scope of activities, the level of funding appears appropriate.

Reviewer 6:
The reviewer commented the project essentially remains at the stage of preliminary ideal material screening with qualitative comparisons. A systematic level of resources leveraging does not seem to be necessary to achieve the claimed goals.

Reviewer 7:
The reviewer found that progress seems to be relatively slow, and more resources may be necessary to accelerate the development of these non-urea sources of NH_3.

Presentation Number: acs032
Presentation Title: Cummins-ORNL Emissions Cooperative Research and Development Agreement (CRADA): NO_x Control and Measurement Technology for Heavy-Duty Diesel Engines, Self-Diagnosing SmartCatalyst Systems
Principal Investigator: Bill Partridge (Oak Ridge National Laboratory)

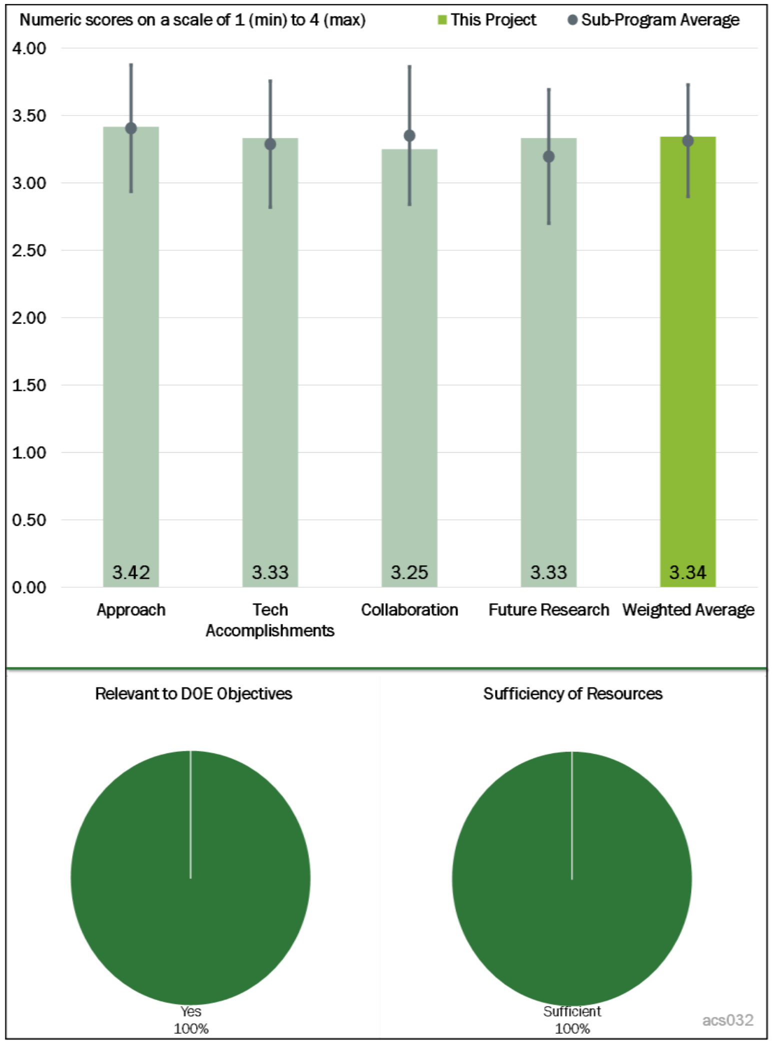

Figure 1-15 - Presentation Number: acs032 Presentation Title: Cummins-ORNL Emissions Cooperative Research and Development Agreement (CRADA): NO_x Control and Measurement Technology for Heavy-Duty Diesel Engines, Self-Diagnosing SmartCatalyst Systems Principal Investigator: Bill Partridge (Oak Ridge National Laboratory)

Presenter
Bill Partridge, Oak Ridge National Laboratory

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer said this CRADA has produced some very great instrumental developments. A conversion inflection is a second order effect and as such is more difficult to measure. However, this work has shown a great level of consistency and seems to be able to predict catalyst trends. The inflection trends for light-off curves have been observed for some time. However, this work shows a consistency that give confidence to its predictions. The reviewer found the mechanistic prediction interesting and it appears to be a reasonable explanation of the phenomenon.

Reviewer 2:
The reviewer pointed out that finding novel, cost effective approaches to meet on-board diagnostics (OBD) requirements is of considerable interest to OEMs. This method, using a conversion inflection to diagnose the aged state of an SCR catalyst, falls into that category. The reviewer noted that determining the best way to use a NO_x sensor to obtain this information may be challenging in exhaust conditions.

Reviewer 3:
The reviewer found this to be a novel topic and insightful. This is a relatively novel area of modeling Cu state in SCR of NO_x. The reviewer observed a well-defined project and well thought out. The reviewer commented that the project relies well on published literature and on its approach in relating conversion inflection to the state of Cu.

Reviewer 4:

The reviewer remarked the project has a good balance of modeling and experimental work in parallel.

Reviewer 5:

The reviewer noted the idea of using transient measurements for the development of more accurate SCR models is novel because transient experiments tend to reveal more information about the reaction pathways and mechanisms involved than steady-state experiments. It is clear that the nature and trend of the conversion inflection (CI) phenomenon are correctly captured by the model, but the model validation by direct (side-by-side) comparison of the model predictions and experimental data obtained under the same condition seems to be difficult to find from the presentation (e.g., Slides 21 and 22). Also, the real test would be to integrate the kinetic model developed here with a catalyst thermal model and see how well the model predictions compare with NO_x conversion vs time measured during vehicle emission tests. The reviewer questioned whether this is part of the future plans.

Reviewer 6:

The reviewer said that using SCR Cu-redox approach to formulate SCR reaction with help of a number of very well-defined transient steps is a technically sound approach to understand CI behavior without going into too detailed micro-kinetics. However, it is not clear how significant it is with this CI behavior understanding practically, because this only happens in a very limited condition, even though there may have some academic value there. The reviewer was not convinced if this CI behavior has anything to do with OBD, where authors believe that this would be the case otherwise.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said what was especially impressive is the project team's ability to develop a simple global explanation for the phenomenon. The intuitively simple connection to the copper oxidation state confirms previous speculation. However, this work translates that speculation into a mathematical model. What the project team calls the half-cycle imbalance, to the reviewer is the gradual shift in consumption of the reactants. Or said another way, it is the gradual shift in a reactive steady state point. It also allows the tracking of the copper oxidation state, which is important in most of the other oxidation-reduction reactions.

Reviewer 2:

The reviewer found this to be nice work to probe the two half-cycles in the copper redox reactions separately to elucidate a mechanism for the conversion inflections, especially because the model appropriately describes transient behavior.

Reviewer 3:

The reviewer said the findings are interesting and can be used in better understanding Cu state in SCR of NO_x. Displaying "fast SCR" reactions at such high temperatures (400°-500° C) is impractical. Equimolar NO-NO_2 is simply not available at those temperatures in SCR of NO_x in diesel emission control. The reviewer said this is not meant to question the CI analysis fundamentals or its value in detailing Cu behavior in SCR of NO_x, but questioning its claim of practical applications for fast SCR in very high temperatures. It is unclear why reduction half cycle and oxidation half cycle kinetic parameters could not have been tackled and included in the deliverables in the first 3 years of this investigation.

Reviewer 4:

The reviewer found that good progress has been made in terms of clarifying the origin of the CI phenomenon and refinements of the reduction/oxidation half-cycles to better match with reactor measurements. Given that many SCR models reported in the literature were developed based on steady-state data, the reviewer inquired about the important features/aspects that are missing or incorrectly captured in the steady-state data-based models. Such information would help advance SCR modeling, but cannot easily be extracted from the presentation slides.

Reviewer 5:

The reviewer detailed this approach relies on accurately measuring the NO_x response of a catalyst when NH_3 is turned on. This may be challenging, given the wide range of exhaust conditions. Also, determining the state of an SCR using this method will require using field aged catalysts as reference catalysts, not oven aged. Also, the effect of poisons must be known. The reviewer found that in general, the characterization work forms a good basis to explore this concept further.

Reviewer 6:

The reviewer said model developed seems to be able to simulate the behavior of CI shown in Slides 21 and 22. However, the reviewer is still not sure how quantitatively accurate the model is. Still, the reviewer found this to be good progress.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked the close working relationship between Cummins and ORNL allows this to be an extremely successful project. The fact that Cummins is the sole provider of the modeling work, which is crucial to this project, demonstrates the tight integration of the research. The reviewer commented that the separation of the task responsibilities gets the most out the strengths of each of the partners.

Reviewer 2:

The reviewer found that partnering with Cummins for HDD aftertreatment is a very good choice. However, having more sensor and catalyst suppliers involved would benefit the project and should provide greater insight on accurately measuring the NO_x and NH_3 in a vehicle application and to characterize the catalyst appropriately.

Reviewer 3:

The reviewer stated that the team is a CRADA, including ORNL and Cummins, and the team appears to be collaborating well. The reviewer suggested that the team including just two partner may be a challenge.

Reviewer 4:

The reviewer observed good team work between the project team and the industry partner. The reviewer found that the work borrows well from the leading edge analyses in the literature. Given the work novelty, the team could have benefited from investigators at Purdue or Notre Dame. The reviewer said though no formal collaborations were established (as a part of this project), the team appears to be aware of such works and has been following them.

Reviewer 5:

The reviewer stated that this project has good collaboration between ORNL and Cummins.

Reviewer 6:

The reviewer commented that Slide 24 shows the collaborations and coordination.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said as with all good projects, the future research falls naturally out of the work already done. The reviewer sees nothing to suggest a missing element in the proposed future research.

Reviewer 2:
The reviewer said this project ends at the end of FY 2018, so the research plan appears to be locked in for this project. The future tasks proposed are all logical next steps of the current work. The reviewer recommended emphasizing the work on the two half-cycle kinetics and the effects of aging on those kinetics. At some point, engine testing will be necessary to evaluate the relevance of these new models to real, fielded systems. The reviewer said please consider adding this task to your scope of work for the next CRADA project.

Reviewer 3:
The reviewer remarked the team has a good plan for future work and for extending the existing work into emission control modeling and on-road applications.

Reviewer 4:
The reviewer recommended that this project should give more attention to field aged catalysts to understand if there are differences in the aging mechanisms that are not captured in oven or dynamometer aged catalysts. Normal operating conditions will expose the catalysts to many difference deactivation mechanisms. The reviewer strongly encouraged continued characterization work.

Reviewer 5:
The reviewer said it would be of practical value to integrate the SCR kinetic model developed here with a catalyst thermal model and simulate NO_x emission as a function of FTP time during engine dynamometer/vehicle tests to demonstrate the advantages of the kinetic model developed in this project.

Reviewer 6:
The reviewer found that the presentation did not give much mention regarding the future work, because the program seems to be completed at given funding.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said the developments from this project have moved smoothly into the development and even production phases of aftertreatment development.

Reviewer 2:
The reviewer pointed out optimizing the fuel and reductant use to obtain the required amount of emissions control is a primary objective of OEMs. The reviewer commented that this work supports that goal.

Reviewer 3:
The reviewer pointed out that modern and future ICEs will continue to need exhaust aftertreatment systems to ensure that criteria pollutants are within limits.

Reviewer 4:
The reviewer commented the project goal, focused on understanding SCR fundamentals, supports DOE's objective for more efficient emission control technologies. Because higher SCR of NO_x is synonymous with

higher engine-out NO_x, itself a means for fuel saving, this undertaking could potentially be integrated in better SCR of NO_x and hence into higher engine-out NO_x yielding fuel savings.

Reviewer 5:
According to the reviewer, lean-burn systems, including diesel engines, are fuel efficient, and improved SCR performance would be critical to their widespread use in the market.

Reviewer 6:
The reviewer said this project can help improve our knowledge on catalyst behaviors, thus developing a better control strategy to improve fuel economy

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that this CRADA always seems successful with the funding that they have.

Reviewer 2:
The reviewer commented that the resources and funding appear to be adequate.

Reviewer 3:
The reviewer said the team appears to have met their objectives with the available budget and other resources.

Reviewer 4:
Continuing the modeling phase, the team is to explore kinetics and to check impact of aging, composition and such on the Cu state. The reviewer found that resources are sufficient.

Reviewer 5:
The reviewer remarked that the resources seem sufficient to carry out the tasks specified.

Reviewer 6:
The reviewer said the project seems to be completed as scheduled.

Presentation Number: acs033
Presentation Title: Emissions Control for Lean Gasoline Engines
Principal Investigator: Todd Toops (Oak Ridge National Laboratory)

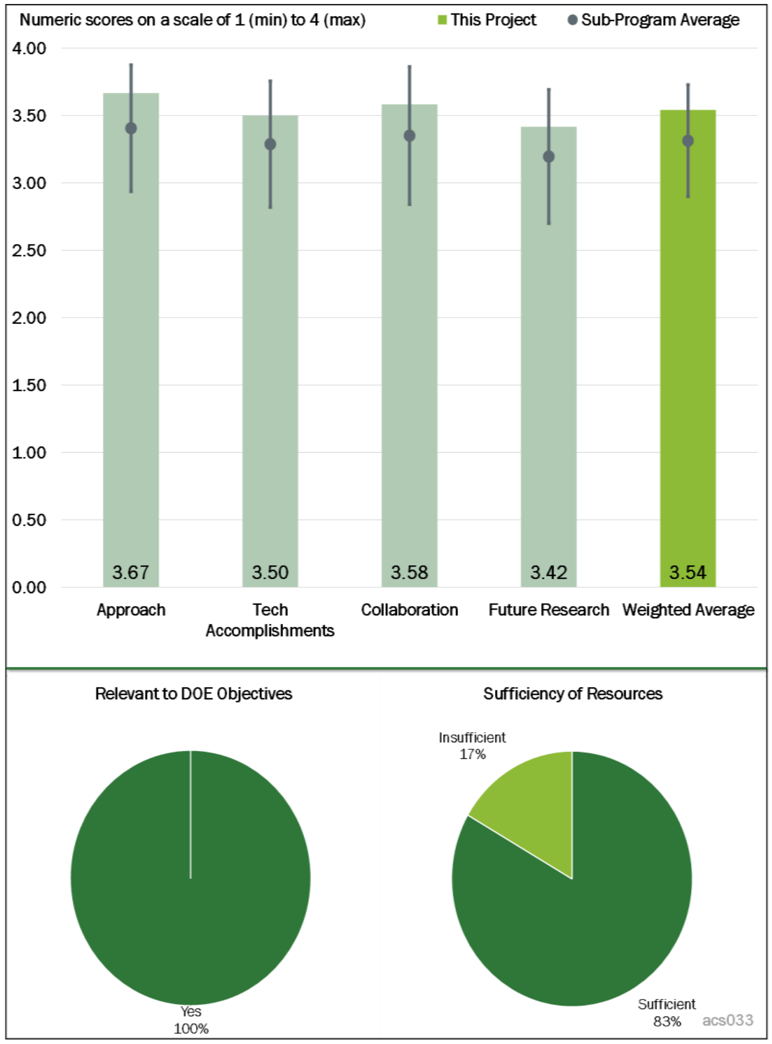

Figure 1-16 - Presentation Number: acs033 Presentation Title: Emissions Control for Lean Gasoline Engines Principal Investigator: Todd Toops (Oak Ridge National Laboratory)

Presenter

Todd Toops, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the approach on this project has evolved well in its 3 years. Evolution of goals and responses is highly expected for such an inherently complicated system with many relevant variables. The approach and the results have led to very useful understanding.

Reviewer 2:

The reviewer commented that the need to address U.S. Environmental Protection Agency (EPA) Tier 3 Bin 30—also known as the 150°C challenge—was clearly highlighted, as was the need to do so within the context of total cost of ownership (TCO). The project also clearly conveyed the role of lean-burn gasoline in achieving this target. The reviewer described the team approach as rational, logical, and a good balance of catalyst development and engine management strategy to ensure synergistic optimization of diverse elements. The application of an iterative development strategy with multiple points of feedback between the researcher, the washcoater and the OEM, to enable discussion and cross-fertilization, was exemplary.

Reviewer 3:

The reviewer said that the approach is well-defined and the researchers have incorporated previous reviewer suggestions in their work.

Reviewer 4:

The reviewer noted that this project directly addresses multiple U.S. DRIVE ACEC barriers. Regarding the first bullet on Slide 23, adding another catalyst may not be welcomed by industry. A zone-coated SCR catalyst might be more promising.

Reviewer 5:

This reviewer described using the BMW engine for lean-burn research as good work. One issue with the engine is that it emits a high level of O_2 during rich operation, which requires using richer A/F ratios to produce NH_3 over the three-way catalyst (TWC). The reviewer explained that this generates the issue with carbon monoxide (CO), although the O_2 during rich operation probably helps with the hydrocarbon (HC) control. Having an engine with less O_2 during the rich periods allows one to operate less rich to make NH_3 while mitigating the CO problem and simultaneously saving fuel.

Reviewer 6:

The reviewer commented that this project is aimed at developing an enabler for widespread use of fuel-efficient lean gasoline engines, for which no cost-effective, reliable, production-ready emission control systems are currently unavailable. The reviewer observed that the project looked into the practical new synthesis from the material development perspective. In the meantime, the team examined on the system level the feasibility of the improved aftertreatment architecture. The project is well-designed overall. The reviewer had minor questions of the project plan, including if a downstream SCR converter will survive a gasoline aging atmosphere, and of how wide the beneficial temperature window is, suggesting more investigations.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer indicated that it is commendable that 0.03 g/mile HC plus NO_x was achieved while saving almost 6% fuel. The optimization work on the ceria content was very interesting. The reviewer offered congratulations on examining the effects of sulfur on the NH_3 production.

Reviewer 2:

The reviewer commented that a range of results have come together well in this project. One of the specific findings in this project, especially with the combination of bench and engine studies, is the issue of NH_3 formation after long lean periods that need to be dealt with.

The reviewer explained that adding the six-mode test from GM and the development of a modified operating strategy more clearly showed the possibilities for passive SCR, especially if the CO cleanup is improved. That the CO emissions are a clear part of the picture is an important accomplishment.

Reviewer 3:

The reviewer thought that the technical accomplishments were good. The fuel efficiency gains after addressing the particulate emissions through use of GPF and CO slip remains to be seen. This reviewer commented that the team should show some pathway to optimization leading to a fuel efficiency gain higher than a 5%-6% gain.

Reviewer 4:

The reviewer remarked that the project appears to be proceeding on schedule. Project goals align well with U.S. DRIVE.

Reviewer 5:

This reviewer commented that a trade-off impact for ceria components for H_2 and NH_3 generation has been reported systematically, and also noted that sulfur impact to the specific aftertreatment system design has been adequately investigated. Engine operation strategy examination has been initiated and modifications are under evaluation. Overall, the reviewer has seen good progress on various key facets, but breakthroughs have yet to be concluded.

Reviewer 6:

The reviewer remarked that clear progress was demonstrated in both catalyst formulation and (sub) optimization of the engine management strategy required to fulfill the targets of the project for both cost and performance. The team has integrated a mixture of bespoke and commercial catalyst offerings to achieve significant improvement in emissions while maintaining a significant fuel savings benefit and have done so while operating within the appropriate cost structure. The reviewer indicated that work on structure function optimization within the TWC (e.g., with regard to the role of ceria and the relative contributions of H_2 [from water-gas shift]) versus CO and HC is insightful and guides the pathway for next developments well. One suggestion would be to examine the possibility of "adsorbate assisted interaction" which can occur between adsorbed NO_x or sulfur oxide and the more reactive HC species, e.g., C_3H_6 or aromatic. This reviewer suggested that a further opportunity for improvement would be further tuning the lean/rich strategy of the engine to concentrate rich phases on the natural acceleration modes of the drive cycle. This would result in more and potentially deeper rich phases, but with a general increase of the total net lean character of the integrated driving cycle. The reviewer added that this would mitigate against the rich NH_3 plume seen at approximately 280 s and would decrease the multiple CO and late-stage HC spikes noted in the tailpipe.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer highlighted that collaborators were very informed and relevant to this project, with one OEM and one catalyst company, along with the University of South Carolina.

Reviewer 2:

The reviewer stated that the team is well-rounded with strong presence from academia, and OEM and washcoater, and that this is a clear strength of the project. The techniques and tools are obviously derived from coherent discussions and agreement, reflecting the strengths of the various partners.

Reviewer 3:

The reviewer observed very good collaboration, with nothing more to suggest.

Reviewer 4:

The reviewer remarked that there appeared to be very good collaborations with GM, Umicore, and other industrial representatives.

Reviewer 5:

The reviewer observed that the project appears to be well-coordinated across multiple partners in industry, national laboratories, and academia.

Reviewer 6:

The reviewer noted that the principle investigators (PIs) have had close interactions with an OEM (GM) and catalyst supplier (Umicore).

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that future planned research addresses the current barriers including CO slip.

Reviewer 2:
The reviewer stated that the future plan of evaluating passive SCR system architecture to maximize fuel savings while meeting Tier 3 emission regulations remains a solid path forward. The potential risk is the team needs more work force to fulfill the tasks on time, as the PI pointed out.

Reviewer 3:
The reviewer acknowledged that the future work is ambitious with a clear pathway. However, this reviewer would caution the team on developing an overly complex system as this naturally lends the overall package open to a larger number of failure modes with increasing interdependency. For example, the “heat sink” catalyst could be removed through better use of energy management system (EMS) strategies to provide both the correct lambda for the system and the appropriate operating temperatures.

Reviewer 4:
The reviewer noted that understanding the factors that could lead to improved fuel economy while still meeting Tier 3 standards is a significant goal to meet before the project is completed.

Reviewer 5:
The reviewer asserted that the future work addresses some key remaining tasks, such as exploring pathways for additional fuel efficiency gains, and improved catalysts and addressing particulates. The reviewer also remarked please consider demonstration on vehicle and transient testing on certification cycles such as Federal Test Procedure (FTP) and US06 to cover a broad range of operating conditions.

Reviewer 6:
The reviewer said that the PI might want to investigate the effect of the rich-side O_2 level on the system performance, at least on the laboratory reactor. With less O_2, the engine can operate less rich to generate NH_3, which will cut down on the CO emissions and fuel consumption.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented that the approach is well-reasoned and sound. The team has demonstrated good progress with clearly evident substantive deliverables. This has been achieved through both individual contribution but also as a function of a cross-functional effort and understanding. The project itself is highly relevant and timely and may offer significant breakthroughs and benefits of high commercial and societal value.

Reviewer 2:
The reviewer reported that this project is well-aligned with DOE goals, particularly those outlined in the U.S. DRIVE ACEC roadmap.

Reviewer 3:
The reviewer stated that the investigations into lean operation are intended to improve fuel economy while meeting stringent emission standards. The project definitely supports DOE objectives of reduced fuel consumption.

Reviewer 4:
The reviewer expressed that, more than many projects, this project clearly looks at the barriers to improving fuel economy with a new strategy for meeting standards with a lean gasoline system.

Reviewer 5:
The reviewer affirmed that, yes, this project takes on one of the most important barriers for adoption of lean burn gasoline technologies, which could offer double digit fuel efficiency gains.

Reviewer 6:

The reviewer said that this project aims at developing an enabler for increasing brake engine efficiency, reducing aftertreatment system cost, and meeting EPA Tier 3 Bin 30 emission standard.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

Of the various projects reviewed in this meeting, this was one of two that the reviewer believed offered the highest potential for a game-changing outcome. To achieve the next level of demonstration—a catalyst/EMS strategy with commercial application—it is clear that more resources will be required.

Reviewer 2:

The reviewer said that the project is meeting its milestones using the supplied resources.

Reviewer 3:

The reviewer acknowledged that the resources seem to be sufficient for the current workload.

Reviewer 4:

The reviewer noted that the resources seem to be sufficient, and that the progress has been satisfactory and in a timely fashion.

Reviewer 5:

The reviewer commented that resources for the project overall appeared sufficient, but it was clear that headcount may have not been sufficient to do all that was desired.

Reviewer 6:

The reviewer observed that contribution from University of South Carolina seems to be less profound if compared with the OEM and catalyst supplier’s involvement.

Presentation Number: acs052
Presentation Title: Neutron Imaging of Advanced Transportation Technologies
Principal Investigator: Martin Wissink (Oak Ridge National Laboratory)

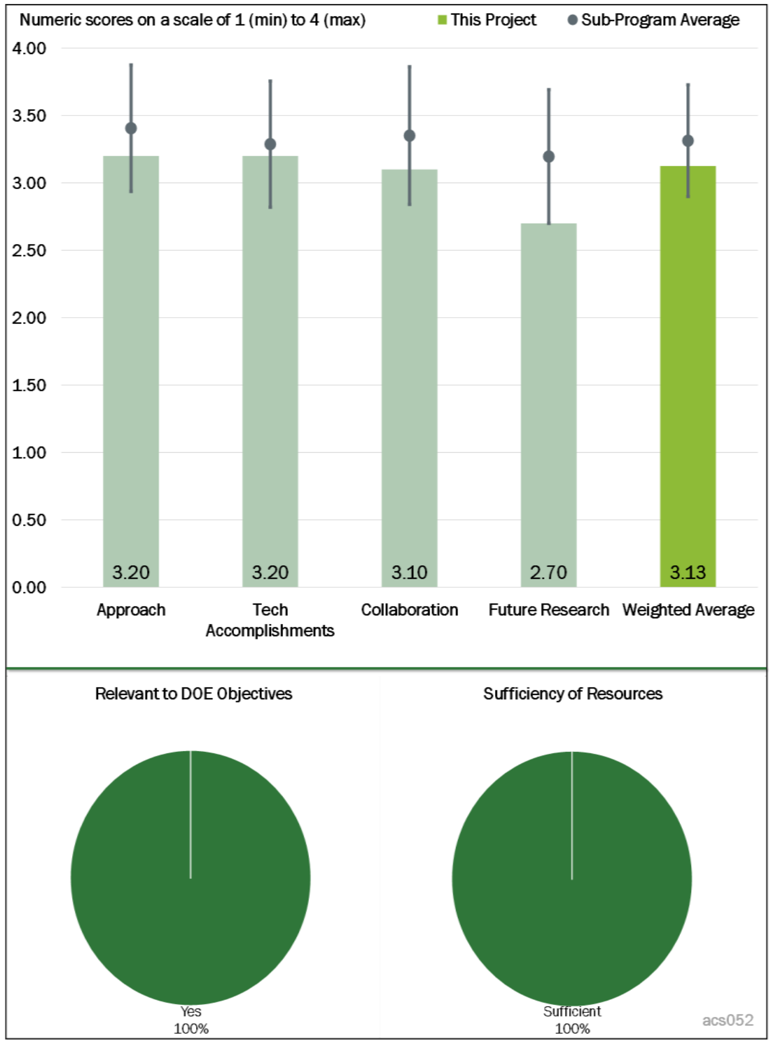

Figure 1-17 - Presentation Number: acs052 Presentation Title: Neutron Imaging of Advanced Transportation Technologies Principal Investigator: Martin Wissink (Oak Ridge National Laboratory)

Presenter

Martin Wissink, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the data collected in the past year shows direct relevance to DOE objectives and provides interesting insight into fuel injection processes. The insight into ball movement and multiple-injection behavior was particularly interesting to this reviewer. The modeling of the imaging technique was a good way to understand the data and the companion data from the X-ray imaging work being done at Argonne National Laboratory (ANL).

Reviewer 2:

The reviewer stated that the development of neutron scanning of engine components is a good approach to expand diagnostic techniques.

Reviewer 3:

The reviewer commented that the approach to this work is good. The main reason this is good rather than excellent is that the pathway to achieve increased neutron resolution is not clear. This may be a real barrier in the experimental quantification of things like fuel injectors. If the project can clearly outline the requirements and resolution and formulate success criteria, this would help. The reviewer concluded that using the approach of combining the neutron imaging data with other information, like the X-ray data, is very good.

Reviewer 4:

The reviewer observed that most of the barriers to high-efficiency engines are due to the inability to meet emissions standards. This project increases understanding of particulate filter performance and regeneration. The diagnostic technique also has potential to improve understanding of the internal dynamics of fuel injectors. All of this information is obtained nondestructively.

Reviewer 5:

The reviewer indicated that this project is very fundamental in nature and attempts to advance the science of neutron imaging techniques and its application to ICEs. The work on the injector is very unclear while the work on the aftertreatment system is very encouraging in understanding the mechanisms of soot deposition and oxidation behavior. The injector work is vague as it is unclear what experimental data are available for model development (e.g., cavitation, droplet behavior etc.) or in general, for furthering the science of sprays/combustion.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the technical accomplishments look to be completed and on track. This project is clearly demonstrating what the current neutron imaging capabilities are and looks to have no problems with engaging the basic science community on improving/aligning the neutron diagnostic toward advanced vehicle technologies.

Reviewer 2:

The reviewer commented that progress over the past year towards the three stated goals has been good. Coordination with the ECN elevates the impact of this work.

Reviewer 3:

The reviewer indicated that the fluid dynamics of several injectors and operating conditions have been understood better with the technique. The team completed a CT of the ECN spray G injector body, and imaged a double injection event. The team procured a large single-hole injector from Bosch to aid in improving resolution of the flow dynamics. The displacement and oscillation of the needle is visible during and after injection. The reviewer further noted that an attempt is being made to quantify the movement. The team obtained more information on GDI particulate characteristics. Soot cake thickness as a function of fuel, length down the channel, and degree of regeneration was accomplished.

Reviewer 4:

The reviewer offered that the imaging results of the fuel injector lack adequate resolution and detail to make strong conclusions. The pintle wobble results seem like a real stretch of the technique. The still shots of the injector cross section are very sharp, but the movies look like fuzzy blobs. The reviewer questioned what could be done to improve resolution for the movies. The reviewer, however, found very interesting and useful results from the GPF soot cake measurements.

Reviewer 5:

The reviewer noted that the technical accomplishments are in general on track; however, it is unclear how the injector data can be used for understanding spray evolution, combustion, and emissions formation. The reviewer questioned whether some of the future experiments could be performed in a combustion constant volume chamber or a flow reactor for understanding combustion and emissions formation. The technique can be used for studying and characterizing performance differences between injectors (e.g., one injector leading to higher HC or soot emissions as compared to another injector). Measurements of dribble can lead to the understanding of HC formation in the expansion stroke.

The reviewer stated that the team should eventually tie this research to combustion experiments. With the proliferation of SCR for both gasoline and diesel combustion, the reviewer recommended studying urea injectors for understanding urea deposit formation mechanisms. Because this project is led ORNL, which has an excellent catalyst/aftertreatment team, please look for internal collaboration opportunities that can provide additional value to the scientific community. The reviewer asked if this technique could be used to assess the degradation of thermal barrier coatings (TBC) (periodic or continuous non-destructive method of TBC thickness measurement) in an engine. This may shed some light on failure mechanisms of TBCs as different TBC materials are being tested in the research community.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that collaboration seemed to be very good in this project. It is likely no small feat to bring the basic science community together with the vehicle technology researchers and other DOE projects. Continued collaboration is encouraged to define what the success criteria are for the different technology imaging and diagnostic areas.

Reviewer 2:

The reviewer observed that this project had good collaboration.

Reviewer 3:

The reviewer noted that good collaboration exists with OEMs and fuel injection system and injector suppliers.

Reviewer 4:

The reviewer observed that there is a high degree of collaboration between academia, industry and national laboratories. The reviewer recommended including Delphi as one of the collaborators in the future.

Reviewer 5:

The reviewer asserted that the mechanisms for coordination were not clearly explained in the presentation. The coordination with ECN is a good start; however, the reviewer questioned if this is being done and what processes are in place to maximize the impact of the imaging work being done at ORNL. The reviewer also asked if the collaboration was mostly with simulation groups or with others as well. Additionally, the coordination with ANL’s X-ray imaging could be more clearly explained and/or stronger as the two datasets seem to be complementary. It seems as though the imaging being done with neutrons and with X-rays is happening at very different length scales (entire injector with neutrons and just the tip with X-rays). The reviewer suggested that if the techniques are complementary, it might be beneficial to image the same injector at similar scales and combine the resulting data.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer was glad to see plans to increase contrast for injector measurements. The reviewer asked if there are any other engine components that would be interesting to image with neutrons.

Reviewer 2:

The reviewer remarked that the future tasks and work look to be good and laid out in a reasonable fashion. The authors could more clearly outline decision points and this may help to guide the program. For example, if the imaging technique and resolution can only provide X and Y is needed, this may help guide and communicate course changes in the future work. Right now, this is still a very new application for neutron imaging, so it is difficult to criticize what is not known.

Reviewer 3:

The reviewer suggested looking for internal collaboration opportunities for using the technique for urea injectors, which may shed some light on deposit formation mechanisms. In addition, once some level of maturity with the technique has been achieved, the reviewer offered that including some combustion experiments (or at the very least, vaporizing sprays) in a spray chamber can shed some light on equivalence ratios, combustion, and emissions formation mechanisms.

Reviewer 4:

The reviewer observed that not a lot of clarity was provided on the future directions of this research. It seems as though there are some loose ends to tie up from the current work, including more imaging of the multiple-injection strategies and imaging throughput increases. However, the longer-term vision for where this needs to go as *research*, not just a tool, was not made clear in the presentation. The reviewer asked what new scientific, or even engineering, questions can only be answered with this type of imaging. It was unclear what breakthroughs the team is planning on working towards in their proposal for the FY 2019 lab call. These questions must be answered more clearly to identify where the core value of this research is going forward.

Reviewer 5:

The reviewer reported that it is not clear as to what is next after the stated list of future work to quantify the needle and ball motion.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that this project supports the DOE goals by providing fundamental understanding of fuel injection, engine, and aftertreatment operation and performance. This understanding and knowledge can then be applied in simulations for industrial use and or industrial contract work.

Reviewer 2:

The reviewer stated that this research provides important information about sprays and injector dynamics for advanced combustion strategies.

Reviewer 3:

The reviewer noted that this project improves understanding of fuel injector dynamics and thus their effect of spray characteristics. This project also provides more understanding of particulate filters. Both these components are key in maintaining and improving the fuel efficiency of engines.

Reviewer 4:

The reviewer affirmed, yes, the project supports the DOE objectives, but is at a low technology readiness level (TRL) scale, which is fine. The project is definitely moving the needle of a new imaging diagnostic.

Reviewer 5:

The reviewer observed that neutron imaging has shown insights into the behavior of soot in GPFs, which is useful to engine manufacturers. The application of the fuel injector imaging is less clear.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the resources seem sufficient for the proposed outcomes. Funding for detector development was good, as are the funding levels for the work itself.

Reviewer 2:

The reviewer observed that the resources are sufficient considering an increase in funding in FY 2018 for detector development. This is the key area where this neutron imaging likely needs to improve for vehicle technology research.

Reviewer 3:
The reviewer stated that the funding is adequate.

Reviewer 4:
The reviewer highlighted that it sounds like beam time availability is not an issue anymore. Further, the reviewer said that resources are sufficient.

Reviewer 5:
The reviewer asserted that the FY 2018 budget of $300,000 is reasonable for the project.

Presentation Number: acs054
Presentation Title: Rapid Compression Machine (RCM) Studies to Enable Gasoline-Relevant Low-Temperature Combustion
Principal Investigator: Scott Goldsborough (Argonne National Laboratory)

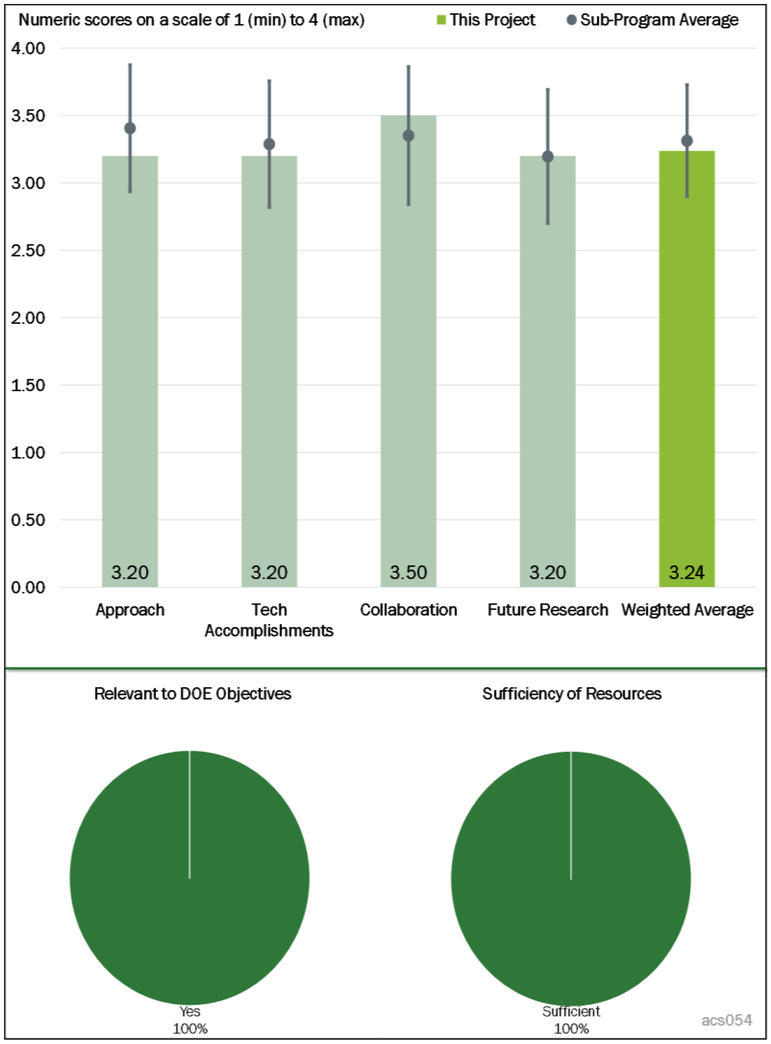

Figure 1-18 - Presentation Number: acs054 Presentation Title: Rapid Compression Machine (RCM) Studies to Enable Gasoline-Relevant Low-Temperature Combustion Principal Investigator: Scott Goldsborough (Argonne National Laboratory)

Presenter

Scott Goldsborough, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that this project supports several other VTO projects, such the development of surrogate fuel chemical kinetics. The project is properly managed and the PI demonstrated progress from last year.

Reviewer 2:

The reviewer commented that RCM work is useful to establish kinetic fundamentals. Coordination with others through the workshop is useful.

Reviewer 3:

The reviewer stated that the approach is laid out clearly and effectively. The reviewer had nothing much more to add.

Reviewer 4:

The reviewer believed that the technical barriers either have been or are being addressed, depending upon the specific barrier. The RCM project is well-designed and feasible.

Reviewer 5:

The reviewer suggested that the project should begin studying individual fuel molecules for properly deriving functional-group methodology, before studying complex mixtures such as surrogates.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer observed good accomplishments and progress in modeling and testing. Organizing the RCM workshop is a great move and contribution.

Reviewer 2:
The reviewer stated that the project is on track with its objectives. The PI demonstrated very good progress from last year's presentation.

Reviewer 3:
The reviewer noted that good progress has been made to extend data to more representative fuels and engine relevant conditions. In particular, ethanol effects are being investigated in a useful way.

Reviewer 4:
The reviewer said it seems that the team has organized the national and international RCM community, which will enable them to establish a database of reproducible measurements.

Reviewer 5:
The reviewer indicated that the Task 1 accomplishments include acquiring an impressive amount of experimental data, which produced improved understanding of the effects of ethanol. The E10 certification gasoline experiments (Task 2) also exhibit acquisition of an impressive amount of data and the analysis of LTC and intermediate temperature chemistry regimes is of value. The presentation skips Task 3, leaving this reviewer wondering what was/is/will be the subject of that task. Only one slide is devoted to Task 4, showing some experimental results and stating—without graphics—that the comparisons with the updated LLNL model are good. A bit more detail, such as a graphical comparison, would be beneficial. The reviewer concluded that the completion of Task 5 is a commendable accomplishment.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer highlighted good collaborations all around. The PI appears to try really hard to share information with other groups and to fit into multiple subjects at multiple levels of collaborations.

Reviewer 2:
The reviewer expressed that ANL is coordinating with what appears to be all of the important contributors in this research area.

Reviewer 3:
The reviewer noted that the PI showed a lot a collaboration and coordination with the national laboratories. The reviewer was not sure how much collaboration can be done with the industry considering the fundamental goals of this project, but suggested more collaborations with U.S. universities. All the academic collaborations that the PI presented are with universities outside the United States. The reviewer did not understand how the PI does not collaborate with U.S. universities when there is so much activity in academia related to RCM work and analysis.

Reviewer 4:
The reviewer acknowledged that coordination of the workshop is a very good idea. Coordination using a MOU is also important. The reviewer questioned why there were no U.S. universities in the list of collaborators.

Reviewer 5:
The reviewer said that ANL has at least two shock tubes. These are local resources that the authors should take advantage of. The authors should strongly consider to include such shock tube results as reference for validation.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that future work supports the VTO goal on improving kinetic mechanisms for conventional and advanced fuels. The results will benefit multiple other projects across DOE.

Reviewer 2:
The reviewer noted that project plans were developed in collaboration with modelers and engine experiments so the results will be useful and relevant.

Reviewer 3:
The reviewer asserted that the proposed plan looks promising and aligned with the milestones. It is going to be very interesting to see how computational calculations can help to figure out the facility-to-facility measurement differences.

Reviewer 4:
The reviewer said that the ANL researchers appear to have identified all of the appropriate next steps for their portion of the overall project.

Reviewer 5:
The reviewer observed that, at this point, instead of moving toward complex mixtures, the team should go back to study single compounds and model them individually. Once this knowledge is established, models can be developed from the combination of the data from the individual molecules. Mixtures can only be understood if the reactions from the individual components of mixtures are also understood.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer asserted that the project addresses uncertainties in ignition characteristics of fuel variants in advanced combustion conditions. It is very relevant to the DOE objectives.

Reviewer 2:
The reviewer acknowledged that, yes, the project supports the overall DOE objectives. Work on developing accurate chemical kinetics for real fuels is extremely important for VTO goals.

Reviewer 3:
The reviewer reported that this kind of work establishes the base of scientific data needed to develop models and experiments for improvement of engine efficiency and emissions.

Reviewer 4:
The reviewer stated that ANL’s twin-piston RCM is being used to acquire autoignition data, over the appropriate ranges of engine-like conditions but without the complications inherent in actual engine tests, such as turbulence, to synergistically improve LLNL’s chemical kinetics models.

Reviewer 5:

The reviewer indicated that the study mainly focuses on transportation-relevant fuels.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer recommended increasing the funding to encourage collaboration with U.S. universities if funds are available.

Reviewer 2:

The reviewer said that the funding seems about right to support continuation of this work.

Reviewer 3:

The reviewer offered that it seems like the resource is just enough for the milestones.

Reviewer 4:

The reviewer stated that ANL’s resources appear to be entirely sufficient for this project, as the reviewer understand it.

Reviewer 5:

The reviewer commented that the authors have organized efforts in a variety of R&D centers, crucial for validation.

Presentation Number: acs056
Presentation Title: Fuel-Neutral Studies of Particulate-Matter Transport Emissions
Principal Investigator: Mark Stewart (Pacific Northwest National Laboratory)

Presenter

Mark Stewart, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

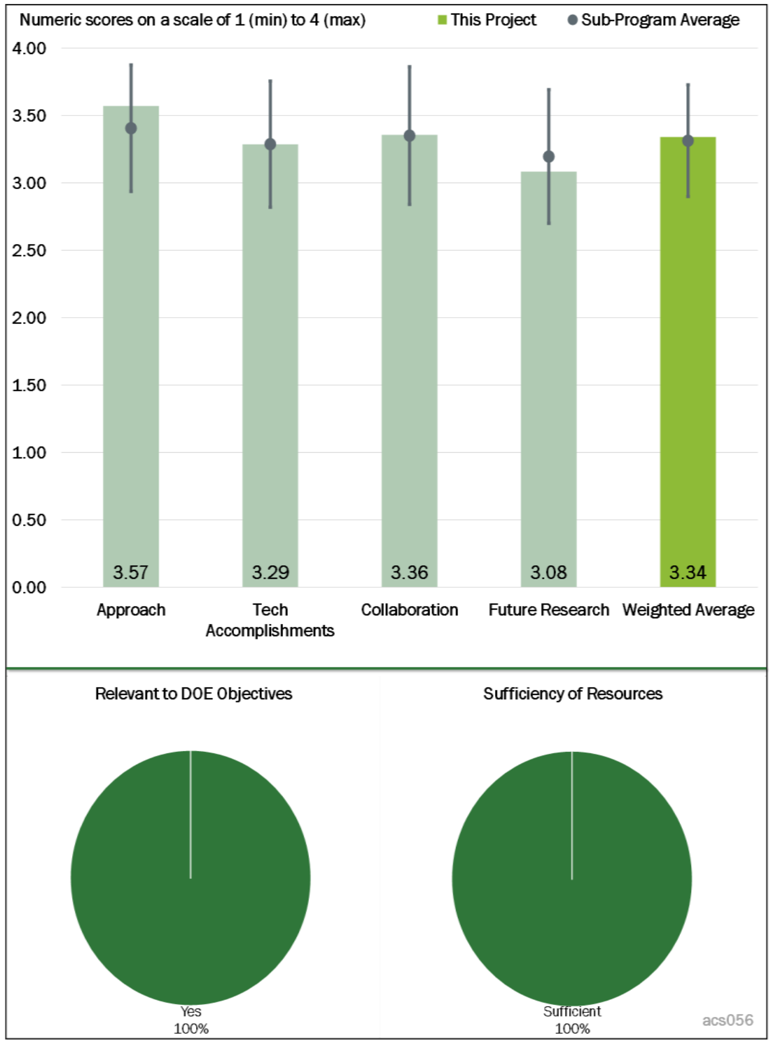

Figure 1-19 - Presentation Number: acs056 Presentation Title: Fuel-Neutral Studies of Particulate-Matter Transport Emissions Principal Investigator: Stewart, Mark (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the researcher is developing a model to describe the particulate matter (PM) transport in a particulate filter. The reviewer believes the researcher should be commended on the length to which the team evaluated several models to develop an acceptable model for PM transport.

Reviewer 2:

The reviewer reported that, overall, this was a well-organized project focused on most of the salient issues. The project has a fundamental focus on practical issues associated with particulates collection and analysis.

Reviewer 3:

The reviewer stated that the overall approach is excellent. The reviewer wished to emphasize the statistical nature of this project, and encourage the researchers to analyze several microstructures for a given porosity / pore size combination and present results with error bars.

Reviewer 4:

The reviewer commented that the project addresses the need for a better understanding of the underlying mechanics of filtration through both modeling and experiment. The work includes a good mix of experimental characterization and modeling/tuning. The PI has done a good job working with university researchers and developing industry relationships.

Reviewer 5:

The reviewer observed that the use of capillary flow porometry (CFP) to determine the distribution of throat sizes should be a useful tool for characterizing the different filters. It is commendable that the team is considering ash and catalyst coating effects on the flow through the washcoat. The reviewer questioned if the model could also account for PM that accumulates between regenerations.

Reviewer 6:

The reviewer commented that the team was developing a range of models to characterize contributing DPF pore volume (filtration mechanisms, simulation of flow and PM filtration). The reviewer observed that the team is also attempting to correlate these with observations. This is a sound and well-reasoned approach. However, as highlighted by others, these simulations should focus more on the behavior of washcoated DPFs/GPFs. Indeed, a challenge would be if the models themselves could be used to anticipate washcoating distribution; moreover, how washcoat distribution could be manipulated to enhance catalyst function and/or flow distribution/filtration of the monolith. In addition, the reviewer added that there does appear to be a multiplicity of models applied to a range of filters. The reviewer requested some additional comments on the strengths/weaknesses that are required for this. The reviewer suggested an effort to produce a final model which augments the best of the various models and could be used as a predictive or diagnostic tool for OEMs, washcoaters, or system integrators.

Reviewer 7:

The reviewer indicated that this project addresses the fundamentals of PM migration and filtration for SI engine emissions. The mathematical model and the collaborative approach of leveraging experiment capabilities at PNNL, University of Washington (UW), and Massachusetts Institute of Technology (MIT) makes general sense for relevant GPF systems.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the relatively good agreement between the experimental data and the lattice-Boltzmann model predictions is quite commendable. The development of the different models (heterogeneous multiscale filtration, cylindrical pore, constricted tube, modified spherical collector, etc.) definitely fulfills the simulation mission of Crosscut Lean Exhaust Emissions Reduction Simulations (CLEERS).

Reviewer 2:

The reviewer noted that characterization techniques for filters seem to be coming along well. The various models in development appear promising.

Reviewer 3:

The reviewer commented that to support the modeling studies, experimental facilities have been newly developed for realistic filter efficiency measurement. Multiple modeling studies have been conducted after taking the catalyst washcoat and ash accumulation into consideration. The finishing project has delivered the goals that the team committed.

Reviewer 4:

The reviewer affirmed that the progress made is excellent. It would have been good to include more statistics, analyzing more samples per porosity/pore size combination.

Reviewer 5:

The reviewer said that technically the researcher had done excellent work on the model. The work would have been technically more complete if it was validated with real engine PM emissions.

Reviewer 6:

The reviewer observed that using CFP is interesting and well-executed, as is the use of tomography. The major concerns here are the use of an overly-simplified test set-up for experimental corroboration. The reviewer looks forward to the completion of the engine re-build and more complexity in the filtration studies.

Reviewer 7:

The reviewer indicated that the team has made good progress. However, the project outputs appear somewhat limited and diffuse in terms of focusing in on the critical issues in DPFs.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that strong collaborative efforts between academia, national laboratories, and industry are evident. This has allowed strong work on the fundamentals while keeping an eye to real life applications.

Reviewer 2:

The reviewer observed that the researcher had excellent collaboration.

Reviewer 3:

The reviewer expressed it is evident that there is very good collaboration with the Engine Research Center (ERC) and MIT.

Reviewer 4:

The reviewer stated that there is a well-developed team comprising academic and OEM partners. Given the fact that most filters are coated, it is suggested that the addition of a washcoating partner to the collaboration would be advantageous and provide additional insight and feedback.

Reviewer 5:

The reviewer said that the team partners appear to be focused on collaboration and contributing to the overall project success.

Reviewer 6:

The reviewer commented that a continued collaborative effort with university and OEMs is appreciated.

Reviewer 7:

The reviewer offered that it will be good to get confirmation from a substrate manufacturer and catalyzer on the results obtained.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the program is ending; however, the researcher did lay out a pathway to complete the work. The reviewer would have rated this a four if the work was continuing.

Reviewer 2:

The reviewer commented that even though the project is ending this year, there appears to be solid amount of work planned with the CFP work, the EFA work, and the collaborative work with Justin Kamp at MIT.

Reviewer 3:

The reviewer said that the end of project appears to have been effectively planned. As for the impact of ash, integrating ash chemistry interactions with substrate properties would be highly beneficial in advancing the value of this analysis. MIT, Volvo, Lubrizol (Ewa Bardasz), and Aerosol and Particle Technology Laboratory have done a fair amount of ash chemistry analysis, which could be of great value to this investigation.

Reviewer 4:
The reviewer highlighted that while this project is closing, it will be useful to demonstrate a path to extending the pore scale analysis to filter scale, and to include some work on statistics (multiple samples for similar porosity/pore size).

Reviewer 5:
The reviewer noted that the plan for the next phase of the project (if funding will continue) is solid and reasonable from a modeling perspective. However, a potential risk is the lack of experimental studies from other groups or literature to support the future studies on multi-functional devices.

Reviewer 6:
The reviewer reported that the project focused correctly on completing tasks in hand. The reviewer further suggested that seeking input and feedback from a coater would enhance this aspect.

Reviewer 7:
The reviewer warned that the challenges do not look like they will be met with the planned future work.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that the project has excellent alignment with overall DOE objectives.

Reviewer 2:
The reviewer noted that, yes, this project helps to improve fundamental pore space characterization and will ultimately help improve performance of filters.

Reviewer 3:
The reviewer remarked that this project is relevant to DOE goals because it is a technical enabler for more efficient, less restrictive particulate traps, which will enable higher fuel economy.

Reviewer 4:
The reviewer commented that the project has a sound and structured approach to the R&D. It is making good progress in producing models to address specific aspects of the challenges in the field of PM filtration with good coordination and collaboration with external partner (except for a washcoater). The work will have direct impact and input into the field of PM filtration and the future focus on diesel is certainly appropriate.

Reviewer 5:
The reviewer observed that the project goals align well with portions of the U.S. DRIVE ACEC roadmap.

Reviewer 6:
The reviewer said that all engines (including advanced engine and combustion concepts that provide reduced fuel consumption) may need GPFs to satisfy the most stringent PM standard of 1 mg/mile. Thus, there will be a need in the future for good models of GPFs to help design exhaust systems that satisfy strict emission standards.

Reviewer 7:
The reviewer suggested that PM emission control for gasoline engine exhaust is critical as the USCAR 2018 Roadmap pointed out. Fundamental and quantified understanding of factors affecting filtration mass and number efficiency is critically anticipated.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer indicated that there were excellent resources and facilities at the partner laboratories.

Reviewer 2:
The reviewer reported that funding is well-balanced versus the scope of activities.

Reviewer 3:
The reviewer highlighted that the program is ending so the effort needs no further resources. The reviewer further recommended that more work be done in this area, perhaps at a university.

Reviewer 4:
The reviewer offered that the project appears sufficiently funded.

Reviewer 5:
The reviewer said that the resources for this project appear to be sufficient, especially because the project will be ending this year.

Reviewer 6:
The reviewer asserted that the resources are sufficient, but to improve on the statistics, more computational resource may be needed.

Reviewer 7:
The reviewer stated that the project made good leverage of the resources in current work. The possible continuation of the project may require more input of joint effort from OEMs and catalyst suppliers to provide comprehensive picture of the complicated experimental observations.

Presentation Number: acs075
Presentation Title: Advancements in Fuel Spray and Combustion Modeling with High-Performance Computing (HPC) Resources
Principal Investigator: Sibendu Som (Argonne National Laboratory)

Presenter

Sibendu Som, Argonne National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

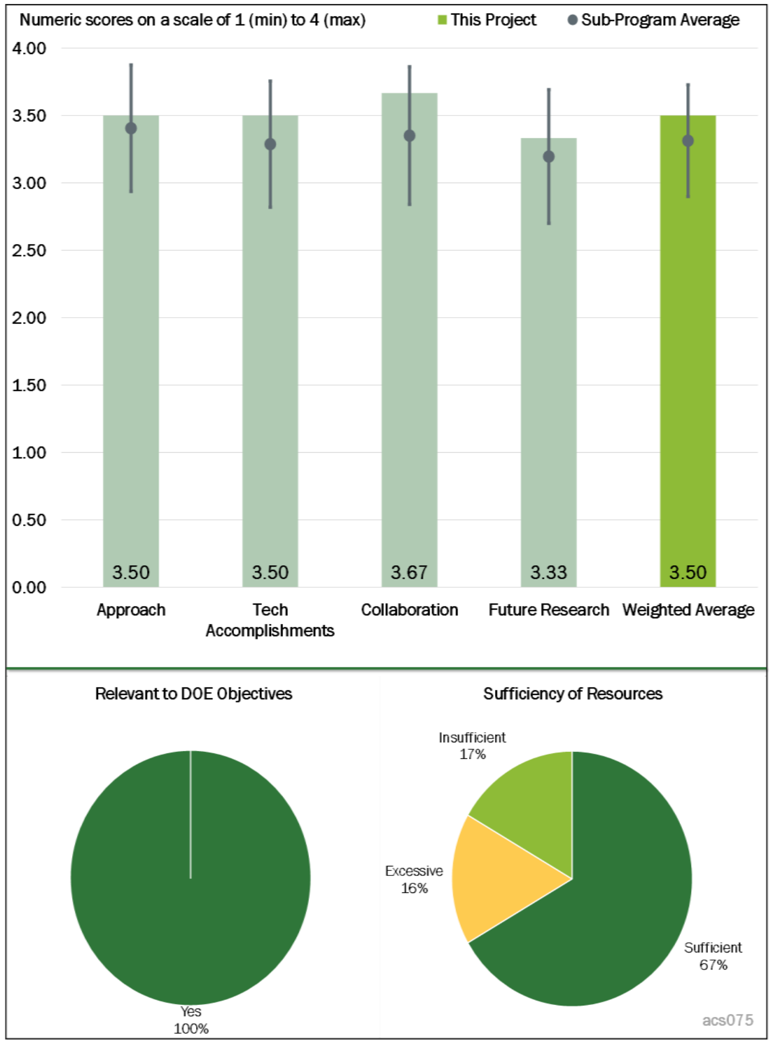

Figure 1-20 - Presentation Number: acs075 Presentation Title: Advancements in Fuel Spray and Combustion Modeling with High-Performance Computing (HPC) Resources Principal Investigator: Sibendu Som (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project was very exciting to the reviewer. It is interesting to think back 20 years to forecasts on computing power growth and the associated impact for simulation capability. It can be seen how those predictions are being achieved in work like this. Each of the subtasks in the project appear to be making huge strides in tackling significant limitations of current modeling approaches, and are showing results that bring the simulation much closer to real-world hardware performance.

Reviewer 2:

The reviewer stated that the project uses two ways to contribute to the community. First, high-fidelity simulations of engineering problems using HPC to reveal fundamental mechanism behind the observed phenomena. Secondly, developing engineering computational models for engine combustion simulations. Both approaches are feasible. The issues addressed by the project, including nozzle flow and its consequence in spray, SI, and turbulent combustion, are critical problems for the industry. The reviewer concluded that the project is well-designed, overall. Although it is not critical, model development using an open-source code will be more generic, more extendable, and have a wider impact.

Reviewer 3:

The reviewer commented that the project approach is well-aligned with the technical barriers identified. It is very relevant to the community and particularly industry demands.

Reviewer 4:

The reviewer noted that the work being done by the PIs and their team directly addresses several barriers outlined by DOE. The PI made it clear throughout the presentation how each task was addressing a particular barrier, both in terms of developing further insight into physical processes as well as enhancing computational capabilities through high-performance computing.

Reviewer 5:

The reviewer observed that many resources and manpower have been invested in “computing” itself. The results for this project are very impressive. It would improve the program if there were more “physical modeling activities” to explore the physics/chemistry of the complex engine process.

Reviewer 6:

The reviewer remarked that several areas of engine combustion (sprays, ignition, turbulence, and combustion chemistry) are being addressed with state-of-the-art models and state-of-the-art computing (exascale). Sub-models for each of the key areas are being developed and validated against data from several collaborators.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed that the progress of the project is excellent. A quantity of stored energy is defined to link the cavitation phenomena with its impacts on structure. The predicted distribution of pressure and stored energy is consistent with experimental measurement, indicating that the stored energy is a good indicator for erosion. Comparison of numerical results using nominal and real geometry shows difference in spray structure. This implies that the spray is very sensitive to the geometry of nozzle, highlighting the importance of the real geometry for spray simulations.

The reviewer also stated that the Euler-Lagrange Spray Atomization (ELSA) model has been applied to simulate the multi-hole GDI injector. A discrepancy was observed in comparing the predicted velocity with measurement, even worse than simulations with return on investment. It indicates that the model needs improvement. This reviewer further acknowledged that the Lagrangian-Eulerian Spark-Ignition (LESI) model is developed for the conventional spark plug. The model has been extended to low-temperature plasma with energy and species deposition. Further development and validation over a variety of conditions are needed by the LESI model. The PIs applied artificial neural networks (ANN) for flamelet tabulation to replace the flamelet with an ANN, which significantly reduces memory usage and speeds up computation.

Reviewer 2:

The reviewer asserted that the progress on the project and the individual tasks is really good. In each of the areas, results are seen which show improved predictive performance and, in a number of cases, the tools are ready to be distributed out for use by other groups.

The only area where this reviewer would like to see additional work is in developing ways to use some of these tools in less than HPC-level computer systems. It does appear that the spray modeling is the highest CPU resource, but the detailed combustion still looks like it is fairly intensive as well (though the team has made massive strides in fixing this). The reviewer was very interested in finding out if there are ways that the team can take the learnings from these super-detailed models and use that to support development of higher-level models that capture the behavior for faster simulation speeds. The reviewer assumed that this is a totally new task or maybe even new project, but it seems like an important area to add so that the work from this project can impact industry sooner.

Reviewer 3:

The reviewer stated that significant progress has been made in the past year and results of the work are actively disseminated to the scientific community and to the industrial community through publishing and close collaboration with outside partners. In particular, the work on nozzle geometry variation and nozzle wear has made significant strides in understanding of variability in engine combustion processes.

Reviewer 4:

The reviewer highlighted that essentially two projects have been combined. Very good progress has been made on understanding the impact of cavitation on metal damage. The location of cavitation is being predicted well. The team has modeled real versus nominal fuel injector geometry effects to show differences between the two cases. Spray droplet size differences between the two cases have been observed. The reviewer remarked that significant progress has also been made in the modeling of various ignition systems (conventional arc, tuned port injection [TPI], corona discharge).

Reviewer 5:

The reviewer said that this project has made excellent progress. Regarding the ELSA model, the reviewer questioned what was new about it, because it has been around a decade now with number of demonstrations. The reviewer did not understand if it is it taking a new development/improvement or another demonstration with needle movement, and concluded that this needs clarification.

Reviewer 6:

The reviewer commented that many sophisticated models are used within this project. The reviewer wondered if they really need to be so complex. It might be possible to devise simpler models to explore the detailed processes such that engineers can use them an effective tool. If so, then it will be an outstanding accomplishment.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer reported that the list of collaborators within the team is fantastic. There appears to be an excellent interaction both within the team and with outside partners to ensure good transfer of technology out to where it can be used.

Reviewer 2:

The reviewer indicated that the PIs collaborate with a lot of groups within ANL, with the national laboratories, universities and industries. The PIs are also very active in ECN. The reviewer further noted that the Virtual Engine Research Institute and Fuels Initiative (VERIFI) offers another platform for collaborations with industries covering engine OEMs, software vendors, oil companies, and computing service companies. Close interactions with industries ensure the right direction of their research, and bring in valuable comments from different aspects. The collaboration model is the most industry-friendly, the widest one among the DOE AEC section.

Reviewer 3:

The reviewer said that collaborations were very good.

Reviewer 4:

The reviewer affirmed that nice collaborations were utilized. The reviewer expressed concern that this work was done with a specific software. The PI will be questioned consistently, which is due to the nature of the collaboration.

Reviewer 5:

The reviewer commented that the team has close and substantial collaborations with a number of outside partners. Their collaboration with industry is particularly laudable, including both the team’s work with CFD companies to enhance turbulent combustion modeling capability, as well as engine manufacturers, to support advanced engine simulation. The cooperative research and development agreement (CRADA) framework for their work with Cummins was identified as a concern by reviewers in the past, but it seems as though the national laboratories benefit greatly from the arrangement as the collaboration provides a good foundation for doing impactful work. The reviewer further noted that this particular group publishes widely and is actively sharing with other members of industry and the academic community. The authors are also active members of the ECN, and even starting to reach out to the aerospace community, which this reviewer believes will particularly enhance their efforts in turbulent combustion modeling and ignition modeling.

Reviewer 6:

The reviewer noted that very good collaborations exist with GM, several national laboratories and universities, as well as Convergent Science. The reviewer suggested further collaboration with fuel injector suppliers who could benefit from the simulation capability to design injectors with improved spray characteristics.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer highlighted that the PIs plan is further improvements to their models, including the cavitation erosion model, flamelet model, and ignition model. The team has planned model validation, and also plans further extending the models to different applications. The research plan is very feasible.

Reviewer 2:

The reviewer noted that it will be very meaningful to devise faster and accurate models in the future.

Reviewer 3:

The reviewer commented that the future research plans largely look good, and extend the work further from where it currently stands. The reviewer would like to see an additional task that is dedicated to transferring modeling tool function to simpler and more computationally accessible models which can be used by industry on lower performance hardware.

Reviewer 4:

The reviewer stated that the proposed future work is well organized and follows logically from the achievements from this year. Of particular importance is the integration of uncertainty quantification into the simulations, and so that addition will be important. In their work on nozzle wear and ignition, the PIs should consider including a framework for capturing the stochastic nature of these processes for better understanding the impact that these phenomena have on engine performance. For the nozzle wear issue, the reviewer reported that the project work on particular geometries is excellent and the barrier they identified at the end of their presentation (about injection versus wear timescales) is an important issue. There are methods by which the stochastic nature of wear (over the course of time and from one injector to the other) can be captured and more learned from the simulations. Similarly, the issues surrounding stochastic behavior of ignition and cycle-to-cycle variations could also be captured in future work. It would be great to see this integrated into future plans.

Reviewer 5:

The reviewer observed that all the future work proposed is good. Care should be taken to maintain a good balance between gasoline LD and diesel medium-/heavy-duty problems. However, the advised that collaboration with gasoline fuel injector suppliers should be aggressively pursed in order to have a quick impact on improving fuel spray characteristics.

Reviewer 6:

The reviewer suggested that the future research plan is more towards adding details and moving towards higher fidelity. However, the rest of the community, often, cannot afford usage of a supercomputing cluster. It would be nice if the PI could plan to fill that gap. Developing modeling capability with fewer tuning constants would not necessarily mean moving towards complex models, because then direct numerical simulation would be used, which is not affordable by most of the community. In the same regards, it is doubtful if publications of sub models that few can implement and afford can benefit many others.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer noted that the project intends to close the gap between fundamental research and industrial applications by developing engineering models for engine combustion simulations. The Engine OEMs are very likely to adopt outcomes of the project for engine simulation and optimization. The models may improve the accuracy or efficiency of the simulations. The project also investigates some critical issues in engine combustion using high-fidelity simulation to reveal the fundamental mechanism and improve the understanding of the process, which is very important for engine engineers.

Reviewer 2:

The reviewer stated that this project clearly addresses DOE objectives.

Reviewer 3:

The reviewer observed that it is very relevant to DOE objectives.

Reviewer 4:

The reviewer said that the project certainly supports the DOE objectives for clean energy utilization. Understanding of the internal combustion (IC) engine-related physics will help to develop advanced concepts with better fuel economy and less emissions.

Reviewer 5:

The reviewer commented that this work addresses several key DOE objectives, including both vehicle technologies and computing goals.

Reviewer 6:

The reviewer stated that predictive modelling capability is needed to design high-efficiency engines with short design turnaround times. Specifically, the accuracy and speed of simulations need to be increased.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the reduced spending rate for FY 2018 is of great concern. This team is addressing a number of important issues. Given the difficulty of the technical challenges and the effort required to continue the productive collaborations the team has established, it would be unfortunate to see them have to reduce either their technical inquiries or their collaborations due to insufficient funds. In particular, funding for post-doctoral researchers and PI time to support these critical collaborations should be maintained at levels reflective of the expectations put on the team. The funding levels from FY 2016 seem much more reasonable than those from FY 2018, especially given the increasing spotlight put on large-scale simulation and exascale computing.

Reviewer 2:

The reviewer remarked that the funding levels and resources appear to be well-matched to the project needs.

Reviewer 3:

The reviewer acknowledged that the team has access to the world’s top computational facility at ANL. The team is also backed up by the engine test team and X-ray team at ANL.

Reviewer 4:
The reviewer indicated that resources seem adequate for the project plan and milestones.

Reviewer 5:
The reviewer stated that resources are sufficient.

Reviewer 6:
With the resources the group has had, in addition to running computations so excessively, this reviewer expected more accomplishments.

Presentation Number: acs085
Presentation Title: Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization
Principal Investigator: Todd Toops (Oak Ridge National Laboratory)

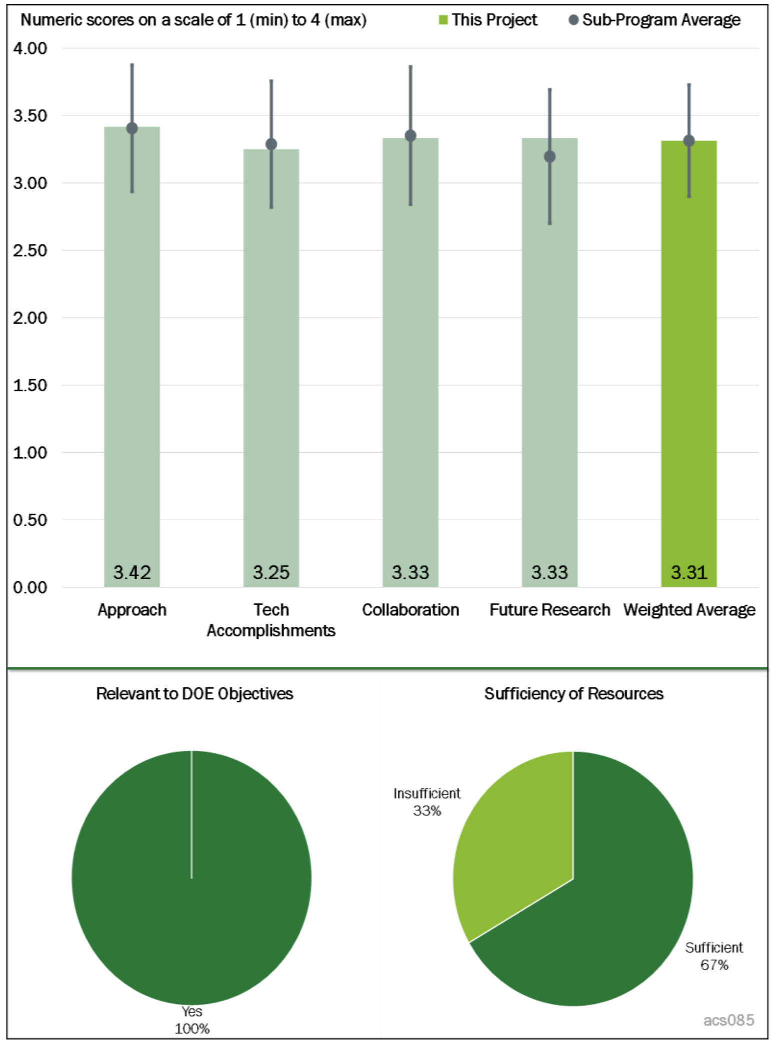

Figure 1-21 - Presentation Number: acs085 Presentation Title: Low-Temperature Emission Control to Enable Fuel-Efficient Engine Commercialization Principal Investigator: Todd Toops (Oak Ridge National Laboratory)

Presenter

Todd Toops, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed good collaboration with both commercial and academic partners. The reviewer also highlighted good diversity over investigating a variety of applications (gasoline and diesel). This project uses a good mix of empirical and first-principle approaches.

Reviewer 2:

The reviewer noted that this approach works to extends Basic Energy Sciences -funded discovery to the engineering application in the vehicle, by evaluating new and promising materials with industrially-focused protocols developed by the CLEERS and ACEC groups. In addition, the reviewer commented that this work is extending the performance of commercial materials by clever modifications to the support materials, designed to improve surface area, activity and durability. In conclusion, the high-risk approach to novel, platinum group metals (PGM)-free metal oxides is extremely interesting.

Reviewer 3:

The reviewer offered that the continued effort in the area of core shell and cerium-zirconium (Ce-Zr) supports the need for LTAT technologies that enable current and future engines to meet increasingly stringent emissions and fuel economy requirements. For example, innovative catalyst solutions for low-temperature oxidation of CO and HC species is strongly supported by USCAR engine and aftertreatment objectives. The inception stage exploration of multiple pathways to achieve high CO and HC oxidation performance is critical to finding viable solutions employing different catalyst technologies in a timely manner. However, the reviewer offered that incorporating poison and aging effects should be done early in the program to properly emphasize/de-emphasize potential catalyst technologies.

Reviewer 4:

The reviewer stated that the team is doing a good job of evaluating low-temperature catalysts. On-engine testing would be preferable, of course, but the reviewer recognizes that this represents a significant increase in scope.

Reviewer 5:

The reviewer reported that collaboration with multiple universities seems to generate some interesting ideas for the formulation of promising low-temperature catalysts. In addition to the activity/durability of low-temperature catalysts, this project also investigates NO_x/HC traps. With the multiple objectives and multiple collaborators involved in this project, however, it is not clear to this reviewer where this project is heading in terms of developing/validating practical low-temperature emission control solutions.

The reviewer suggested that perhaps evaluating various ideas under more severe aging conditions at early stages would help in more clearly defining the primary paths forward. 800°C aging is not severe enough for stoichiometric gasoline engine applications. Also, the reviewer noted that it would be useful to add iso-pentane and iso-octane, and examine other zeolites, beta and CHA, for HC trap evaluation. It was not clear what is being investigated under the "multifunctional catalyst evaluation." The reviewer guessed trapping plus oxidation function. If so, the reviewer questioned what is going on in the HC trap.

Reviewer 6:

The reviewer remarked that not all of the work presented here is exceptionally new. Zr has been commonly used in TWC washcoats to stabilize dispersion and enter into the oxygen storage cycle. It was not clear what was done differently here. The dual bed catalysts are interesting; however, both beds have to have the required durability for the application. The reviewer also believes silica has been added to alumina to stabilize washcoats, which is not new information.

It is well-known that ZSM-5 does not have the required hydrothermal stability. It is not clear if the CHAs have the same hydrocarbon trapping profile. For the sulfur poisoning of the dual bed catalyst, it is not uncommon for the sulfur to migrate to other parts of the catalyst. Repetitive runs would indicate if the sulfur is really removed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that the team has some nice results that provide guidance on low-temperature catalyst formulations and supports. The project also produced good results showing synergy with the dual-bed and mixed-bed systems. The materials seem to need stabilization so that they will function well out to the vehicle or engine full useful life.

Reviewer 2:

The reviewer commented that the work done by this group in the area of Pt/Pd bimetallic catalysts and highly dispersed catalysts to enhance the low-temperature CO and HC oxidation reactions is an important area to address for lean systems. However, the reviewer noted that better understanding is needed of why the bimetallic formulations did not perform as expected. The reviewer questioned if it was the sintering of the particles or the surface composition of the sintered Pt/Pd particles.

With respect to the highly dispersed PGM catalysts, the reviewer expressed that consideration should be given to the manufacturability of the materials. Many times, there is a tradeoff between the PGM cost and the production cost. If the material cannot be produced cost effectively, then it is not a viable material. If that is the case, more effort should be directed toward enhancing the activity and stability of PGM-based catalysts.

Reviewer 3:
The reviewer acknowledged good progress from this project. Some open questions remain, such as consideration of cost versus application (a balance point, a must in this cost-stringent industry), assuming commercial application is in the metrics. Aging considerations still need some work (the team may be out of time because this is the third and last year of the project).

Reviewer 4:
The reviewer observed that good progress has been made in several fronts, but moving forward, it would be necessary to pay more attention to how the team can take advantage of possible synergy between the various ongoing activates (and properly integrate) to come up with practical options for effective low-temperature emission control.

Reviewer 5:
The reviewer noted strong technical accomplishments in the four focus areas. However, the reviewer would have liked to have seen error bars on the bar plots, to distinguish the effects that are real versus the noise of the experimental measurement. The reviewer expressed excitement to see the full-size close coupled converter monolith work.

Reviewer 6:
This reviewer was concerned that the answers to some of the issues could not have been extracted from the literature or had been the subject of unpublished supplier studies. The difficulty with the unpublished supplier studies is getting some of the information from the supplier partner.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer observed strong collaboration between the national laboratory, University of South Carolina, and industrial partners.

Reviewer 2:
The reviewer noted that the project seems to have a good set of partners on the team, and that the ORNL-led team is drawing on the expertise from the partners.

Reviewer 3:
The reviewer said that the work presented here was in collaboration with three universities, which are the University of Buffalo, South Carolina, and Tennessee. Collaborations with other laboratories and an OEM could be improved to help minimize overlap of efforts and to better gauge the potential of the material technologies for production.

Reviewer 4:
The reviewer remarked that the team has successfully integrated both academia and industry (coaters, others) in this project execution.

Reviewer 5:
The reviewer commented that contribution/participation by Johnson Matthey Inc. (JMI) seems weak so far. Effective coordination and integration of various activities from diverse teams would remain a challenge, but this issue will become more important as the ending date of the project is approached.

Reviewer 6:
The reviewer would have preferred some OEM input to the project. It is likely some of these issues have been explored by the OEMs already.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that, in general, the direction of the future work is helpful for optimizing the activity of the catalysts for their applications. However, more consideration should be given to the processing of the material and its viability for cost effective production.

Reviewer 2:
The reviewer noted that the project is in its final year, and so most of the future work identified will need to be addressed in a follow-up project for FY 2019–FY 2021. The team should strongly consider starting to test these materials in actual engine exhaust.

Reviewer 3:
The reviewer offered that the team/project appears to have a sense of what the remaining challenges are and where they want to take this, for instance incorporating CHA (SSZ-13) into the matrix, zirconium dioxide (ZrO_2) and further aging.

Reviewer 4:
The reviewer stated that the technical work is good. The reviewer believed that other suppliers have explored some of this ground. A tighter coordination with the catalyst supplier could reduce reinventing the wheel.

Reviewer 5:
The reviewer suggested that more focus on catalyst aging and other types of zeolites in the future seems to make sense.

Reviewer 6:
The reviewer indicated that questions and feedback (particularly with respect to including lanthanum in the formulations) will be of benefit as this project moves forward.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that this is relevant inception-stage research and consistent with the call for LTAT by USCAR and the needs of the OEMs in general.

Reviewer 2:
The reviewer observed that, yes, the diversity of the team's outreach to work with industry and the needs addressed reflect this adequately.

Reviewer 3:
The reviewer expressed that high-efficiency combustion engines tend to have lower exhaust temperatures, which creates demand for catalytic converters that are active at lower temperatures. As always, demonstration of these novel catalysts on real engines will build credibility.

Reviewer 4:
The reviewer stated that viable/effective practical aftertreatment options for low-temperature emission control are an important enabler for next-generation fuel-efficient engines.

Reviewer 5:
The reviewer remarked that this project supports the DOE goals and that LTAT will be critical to the deployment of LTC engines.

Reviewer 6:
The reviewer noted that it is important to be able to reproduce some of the technology that the suppliers already have explored. It is never clear where the seams are between proprietary and commonly available technology.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that the team seems to have sufficient resources to achieve their project objectives as planned. If engine testing is needed, though, a significant increase in budget will be needed.

Reviewer 2:
The reviewer suggested that, though the team has targeted the right challenges, given the diversity of their project needs, they could benefit from more resources.

Reviewer 3:
The reviewer affirmed that the project has made excellent progress and should continue to be funded at the same level.

Reviewer 4:
The reviewer reported that perhaps there was too much reliance on the outside collaborators. Also, the reviewer suggested that engine testing of promising technologies would require significant additional resources.

Reviewer 5:
The reviewer said that this team got a lot of work done this year.

Reviewer 6:
The reviewer noted that funding and resources are sufficient.

Presentation Number: acs093
Presentation Title: Lean Miller Cycle System Development for Light-Duty Vehicles
Principal Investigator: Paul Battiston (General Motors)

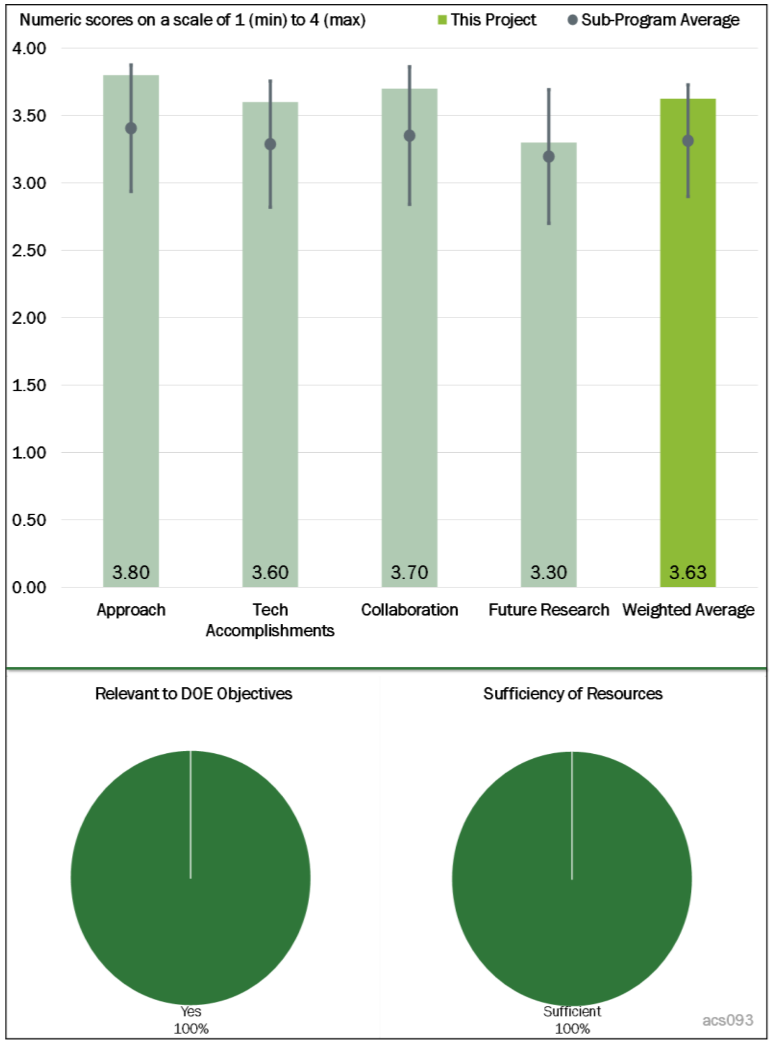

Figure 1-22 - Presentation Number: acs093 Presentation Title: Lean Miller Cycle System Development for Light-Duty Vehicles Principal Investigator: Paul Battiston (General Motors)

Presenter

Paul Battiston, General Motors

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed that the integrated approach from this team is great to see from the OEM showing strength of resources and ability to make gains at higher TRL levels. The project has a good systematic approach at technologies to increase efficiency for lean engine systems with an excellent integration approach for aftertreatment for lean burn. The reviewer remarked the presentation had a clear walkthrough of the team’s efficiency gain strategy.

Reviewer 2:

The reviewer commented that this project is a very nice integration of many technologies that show promise for significant reduction in fuel consumption. Effectively doing this requires very careful matching of the operating characteristics of each component of the multiple technologies being implemented. The approach being followed here is demonstrating a systematic, fundamentally based approach to doing this.

Reviewer 3:

The reviewer noted that the approach of this project is very good. It consists of a comprehensive combustion system, engine systems (boost, valve train), and emission controls approach to reduce fuel consumption. This allows the interactions and tradeoffs to be identified, such as the interactions between efficient combustion, low exhaust temperature, air handling, and emissions control. It is a large program, and the reviewer acknowledged that there was limited time for technical detail. Given that, the reviewer would like to see the data that led to the technical decisions. For instance, the reviewer questioned what the tradeoffs are between the different air handling options, as well as what the tradeoffs are between early intake valve closing and late intake valve closing. The reviewer suggested that these findings warrant some technical papers in the public domain to document these findings.

Reviewer 4:
The reviewer said that lean gasoline combustion is of great interest to the industry and faces many challenges. GM presented a solid development program highlighting and quantifying the benefits and challenges of their approach.

Reviewer 5:
The reviewer summarized that the goal of this project is to develop an engine operating on the Miller cycle with 35% fuel economy improvement over a 2010 baseline. The Miller cycle is interesting; it is a sort of variation of the Otto Cycle. It has been around for a long time and is known to have attributes, such as more power with lower emissions potentially. The cycle is incorporated in some railway locomotives and overseas car manufacturers but apparently not yet in the United States. The reviewer also stated that the stretch goals are impressive; it is hopeful that they can be met.

The reviewer commented that the approach is well developed and carefully thought out. The link of the various components noted in the presentation to the specified fuel economy gains needs strengthening. For example, “advanced thermal management” is noted as providing a 4% gain in fuel economy. The reviewer questioned how this connection was established. Considering only the non-combustion targets, they amount to about half of the expected gains. This is significant. Even if the Miller cycle did not work out, the reviewer proposed that focusing on the other half (stop/start, thermal management, friction/mass, downsizing, etc.) would itself be worthwhile.

When the PI refers to “fuel economy improvement” the reviewer observed that two things must be established. First, precisely define what is meant by “fuel economy.” Second, establish the baseline against which the improvement is compared. The latter is clear. The former is not from the presentation. The reviewer requested that in future presentations the team establish a definition of “fuel economy.” If it means miles per gallon, then state it. If there is another definition please provide it. The author presented a chart that owed “efficiency,” which is not the same as “fuel economy.”

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer noted excellent technical accomplishments and progress that are directly tied to DOE and U.S. DRIVE goals. The systematic approach the team is taking is obviously paying off in terms of technical achievements. This project provides a solid approach at exploring where to focus development efforts to make largest impact on FTP. The reviewer commented that a very good approach was taken evaluating criteria on choosing boost system architecture that meets transient dynamometer and vehicle development goals that focuses on technical aspects and tradeoffs. This is a good example of enabling technology that works with the system constraints and goals. The reviewer further observed good use of CFD in driving multi-pulse injection strategy. The reviewer observed a great presentation of constraints and challenges with NO_x and HC with the lean-stratified region and comparison versus stoichiometry. The honest presentation of these data is very valuable.

Reviewer 2:
The reviewer said that good progress has been made. The team is building and installing the multi-cylinder engine in the test cell.

Reviewer 3:
The reviewer remarked that excellent progress has been made, and the reasoning behind the component choices is clear. The tradeoffs between exhaust enthalpy, engine combustion, emissions control, and air handling are very interesting. The reviewer suggested that additional disclosure of the data behind some the choices would be beneficial. For example, determining the power consumption of the ebooster would be beneficial, as would disclosure of the minimum exhaust temperature required.

Reviewer 4:

The reviewer offered that GM has made good progress on this challenging development program.

Reviewer 5:

The reviewer observed that the presentation contained a carefully thought out list of evaluation criteria with advantages noted. The use of the BorgWarner booster is interesting if cost considerations do not eliminate it. The reviewer noted several questions. First, with regard to the combustion CFD simulations that were noted, the reviewer questioned if these were carried out using CONVERGE or some other code. The reviewer also contemplated how was the spray might have been simulated. The reviewer highlighted that the spray-guided piston configuration was interesting. The reviewer questioned whether there were any constraints on the atomizer (droplet size, velocity, number density, etc.) that the team must consider to optimize performance. The reviewer remarked that the catalyst used was not clear and requested further details be provided. The reviewer questioned if any plans existed to investigate a range of catalysts. The reviewer noted that this project seems well on its way to meeting the targeted efficiency goals. The PI is already at 26% for a 2 bar brake mean effective pressure. Finally, the reviewer requested that the PI comment on the fabrication cost of an engine on overall expected vehicle cost for an engine operating on the Miller cycle. If implemented, this would be an accomplishment for both GM and DOE.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the level of integration across this project shows great collaboration. The team is well-chosen and the approach for collaboration is solid. The presentation clearly notes engagement with 40 suppliers, ORNL for lean NO_x aftertreatment and inter-GM collaborations utilizing great strengths of all involved.

Reviewer 2:

The reviewer commented that the team consists of several strong contributors.

Reviewer 3:

The reviewer said that the list of collaborators is not very long on this project, but it does include the necessary collaborators to bring this technology to the market. So, the level of collaboration is where it needs to be.

Reviewer 4:

The reviewer remarked that the project has the right mix of collaborators from both industry and other national laboratories. The author presented a list, though specifics on precisely what each provided was not given.

Reviewer 5:

The reviewer observed that to build the engine requires working with 40 suppliers.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer observed that proposed future work includes solid go/no-go decisions and continues a solid plan for next stages with multi-cylinder engine development. The remaining challenges also focus on Tier 3 emissions targets. The approach (Slide 8) and milestones (Slide 7) show a path to addressing these barriers.

Reviewer 2:

In the reviewer’s opinion, the researchers have identified the important challenges and barriers that need to be addressed to make this work successful, and have a well thought out plan to address these challenges.

Reviewer 3:
The reviewer said that project plans are logically staged with appropriate decision points. Reasonable and sensible course adjustments have already been made, and others may occur.

Reviewer 4:
The reviewer highlighted that a list of challenges is provided for the future work that included system integration, aftertreatment work, control to manage combustion mode transitions, and others. The reviewer also noted the importance of integrating systems to achieve fuel efficiency and Tier 3 emissions targets. These are all appropriate. The proposal to optimize transient performance, control technologies, and develop a plan for vehicle implementation is good, though somewhat vague in details.

Reviewer 5:
The reviewer remarked that the project is 70% complete and most of the remaining work is focused on developing calibrations and performing multi-cylinder demonstrations. The reviewer would like to see a larger focus on reporting through technical papers. The reviewer acknowledges that there is a large portion of the data that cannot be released publicly. However, as it is an industry project, the public share of funding warrants transfer of some of the data and knowledge developed in this project to the broader technical community.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that this project clearly supports the DOE objectives and U.S. DRIVE efficiency goals and uses as project target.

Reviewer 2:
The reviewer noted that this work represents a well-run program to integrate multiple, technically advanced, fuel consumption reduction technologies into a real-world functional engine.

Reviewer 3:
The reviewer indicated that, yes, from a broad perspective it does support the overall objectives. If successful, a Miller cycle engine in a product line would be a great achievement.

Reviewer 4:
The reviewer commented that this work supports DOE goals of developing and commercializing more fuel-efficient technologies.

Reviewer 5:
The reviewer reported that a stratified lean GDI engine is very relevant to VTO goals and objectives. The speaker highlights the critical importance of cost-effective, durable and effective aftertreatment.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that this is an ambitious project and the resources appear to be well-aligned with the efforts. Internal milestones were extended due to procurement timing.

Reviewer 2:
The reviewer commented that it appears that the funding for the program is sufficient.

Reviewer 3:
The reviewer stated that the project appears to be adequately funded.

Reviewer 4:
The reviewer remarked that this is a very large project ($21 million); however, 50% cost-share shows GM's commitment to this technology.

Reviewer 5:
The reviewer stated that resources seem adequate although ultimate judgement would have to come from a cost/benefit analysis based on DOE's investment relative to the commercialization potential.

Presentation Number: acs100
Presentation Title: Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research—SuperTruck II
Principal Investigator: Justin Yee (Daimler Trucks North America)

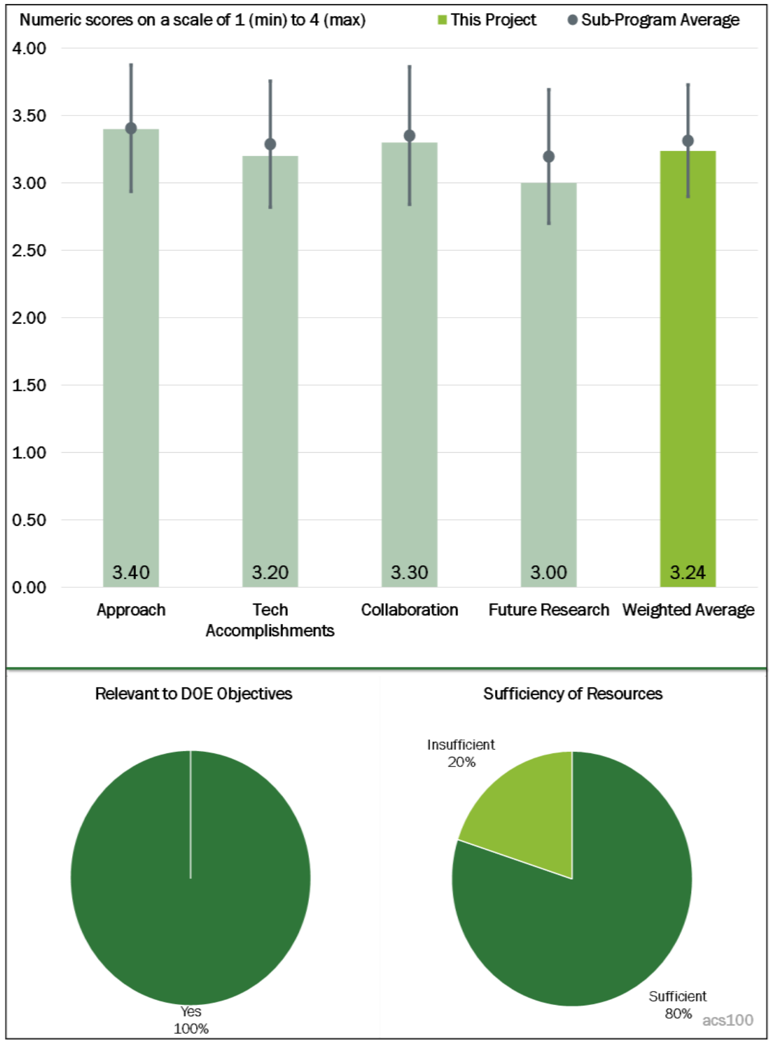

Figure 1-23 - Presentation Number: acs100 Presentation Title: Improving Transportation Efficiency through Integrated Vehicle, Engine, and Powertrain Research—SuperTruck II Principal Investigator: Justin Yee (Daimler Trucks North America)

Presenter

Justin Yee, Daimler Trucks North America

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted no weaknesses. The project is very well organized and systematic.

Reviewer 2:

The reviewer stated that Daimler’s approach is well laid-out and delivering to the program’s expectations. A good example is how the team is approaching the challenge of aerodynamics versus styling versus functionality, as well as implementing a 48 volt (V) system.

Reviewer 3:

The reviewer suggested that a bit more detail on the approach would have been helpful to understand thoroughly both the overall and the specific powertrain.

Reviewer 4:

The reviewer noted that the switch to a 48V system is crucial to this type of hybrid. The aero system seems to be well developed. However, the reviewer stated disappointment that the start-stop system was not in the primary development pathway. The predictive engine and drive systems seem also to have been removed from the major development pathway. Those plus start-stop have appreciable fuel economy benefit.

Reviewer 5:

The reviewer acknowledged that the technical approach described in Slide 4 of the vehicle side contains all of the key technological elements required for this program. Specific improvement targets on each technology look good. Similarly, the approach taken on the engine side (Slide 11) is also good and clear. However, the reviewer observed that there is still a big gap to achieve the program goal as indicated in the gray bar of this slide, which cast the doubts of whether this program can achieve the 55% BTE goal.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the team has made very good progress on initial hurdles in defining various elements.

Reviewer 2:

The reviewer commented that good accomplishments were presented in the multiple areas of aero, powertrain, engine, energy management, and controls.

Reviewer 3:

The reviewer noted that the team seems on track to deliver to the technical requirements making system level decisions. The balancing act of eco-roll versus mild hybrid, and hill climbing versus flat land efficiency are all good examples.

Reviewer 4:

The reviewer observed that this project has focused on the low hanging fruit for improving fuel economy. However, there is a next level that may be needed to reach the goals. The smaller percent improvements like these two maybe required to make the target. The reviewer suspected that there is more to recover using vehicle controls than the 1% estimate shown in Figure 4. Also, the 6% shown from the powertrain might be a little low.

Reviewer 5:

The reviewer said that good progress has been made on aero (Slide 6) and tires (Slide 7). However, it is not clear whether single wide base tires would be used, although the picture clearly shows dual tires. The reviewer questioned why the single wide based tire would be abandoned in such an early stage, where there is clear advantage of single wide base tires over dual tires. The reviewer further commented that technical progress on powertrain seems to be too simplified with only one slide (Slide 12). It could add more details to enhance the program values for reviewers to appreciate. It is not clear what kinds of twin-turbochargers would be used, whether variable-geometry turbocharger or waste-gated. Such vague description would not help the program clarity.

The reviewer was not sure how the proposed predictive engine control (Slide 14) would be able to be implemented into the engine control unit (ECU) with such complicated modeling structure, evidenced by the air path model of this slide. In addition, the fidelity of this type of model in predicting transient behaviors is in question. This modeling approach would be even more in question when the model includes an aftertreatment system, which would make the memory of ECU even more challenging. Furthermore, the reviewer questioned how the authors could credit the SuperTruck I (ST1)'s model-based control algorithms to this program, because this approach used in SuperTruck II (ST2) is totally different from ST1's, where the latter largely relies on a neural network model based on Atkinson's unique approach. Finally, this seems to be not practical even for consideration of use in production. As a result, this reviewer viewed the progress on predictive engine control as backward compared to ST1.

The reviewer remarked that one of the big concerns of the progress would be waste heat recovery (WHR), which is highlighted in Slide 16. Without WHR, it would be hardly believed that this program can achieve the program 55% BTE goal. The progress on WHR should be the key reporting topic in the next review. In Slide 2, the reviewer was confused about why the author added progress on "Basic aero shape development is done…" to the Barriers, which has nothing to do with barriers. Overall, this reviewer concluded that this presentation seems not to be well-reviewed and written, specifically on the powertrain side.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that partner integration in the project appears to be exceptional.

Reviewer 2:

The reviewer noted that this is a well-structured team with many, well qualified partners. Their collaboration and contributions seem significant, and it is good to see not just suppliers as collaborators.

Reviewer 3:

The reviewer offered that this was a strong team, utilizing expertise throughout. The reviewer suggested that all of these ST projects should engage end-users more in their work. The reviewer said that this project had too much reliance on in-house customer knowledge.

Reviewer 4:

The reviewer affirmed that project collaboration and coordination seem to be good, including all major partners (Slide 19).

Reviewer 5:

The reviewer noted that the team did not adequately define the roles of each of the partners.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the work plan going forward is well defined.

Reviewer 2:

The reviewer observed that this team has a solid plan for the rest of the program. The reviewer would like to see some more details on how the systems are being evaluated for total cost of end user ownership.

Reviewer 3:

The reviewer noted that going after the tasks in the stretch goals may be required to make the goal.

Reviewer 4:

The reviewer indicated that the proposed future research shown in Slide 17 seems to be mainly for the vehicle. It would be clearer if a similar slide would be developed for the engine.

Reviewer 5:

The reviewer said that not much detail was provided on future research. The WHR discussion during the question and answer was helpful, but this is aimed at the stretch goal.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that the project has excellent alignment with overall DOE objectives.

Reviewer 2:

The reviewer noted that Class 8 over-the-road tractors consume 80% of truck fuel burned. The SuperTruck project is delivering.

Reviewer 3:
The reviewer reported that all of the improvements shown in this project are directly relevant to getting a more fuel-efficient truck onto the highway.

Reviewer 4:
The reviewer noted that the project aims to improve the engine efficiency and overall freight efficiency for reduction of fuel consumption, which aligns with DOE objectives.

Reviewer 5:
The reviewer noted that this program should be able to substantially reduce fuel consumption, thus supporting the overall DOE objectives

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed excellent resources and facilities at the partner laboratories.

Reviewer 2:
The reviewer noted that the resources appear to be adequate for the program to meet it is objectives.

Reviewer 3:
The reviewer reported that resources were sufficient.

Reviewer 4:
The reviewer believed more manpower needs to be placed on the stretch technologies.

Reviewer 5:
The reviewer commented that it may be sufficient on the total vehicle to achieve the vehicle related goals, but it would be in question whether the team has enough resources and funding on the engine side to achieve 55% BTE goal because of lack of progress on WHR.

Presentation Number: acs101
Presentation Title: Volvo SuperTruck II: Pathway to Cost-Effective Commercialized Freight Efficiency
Principal Investigator: Pascal Amar (Volvo Trucks North America)

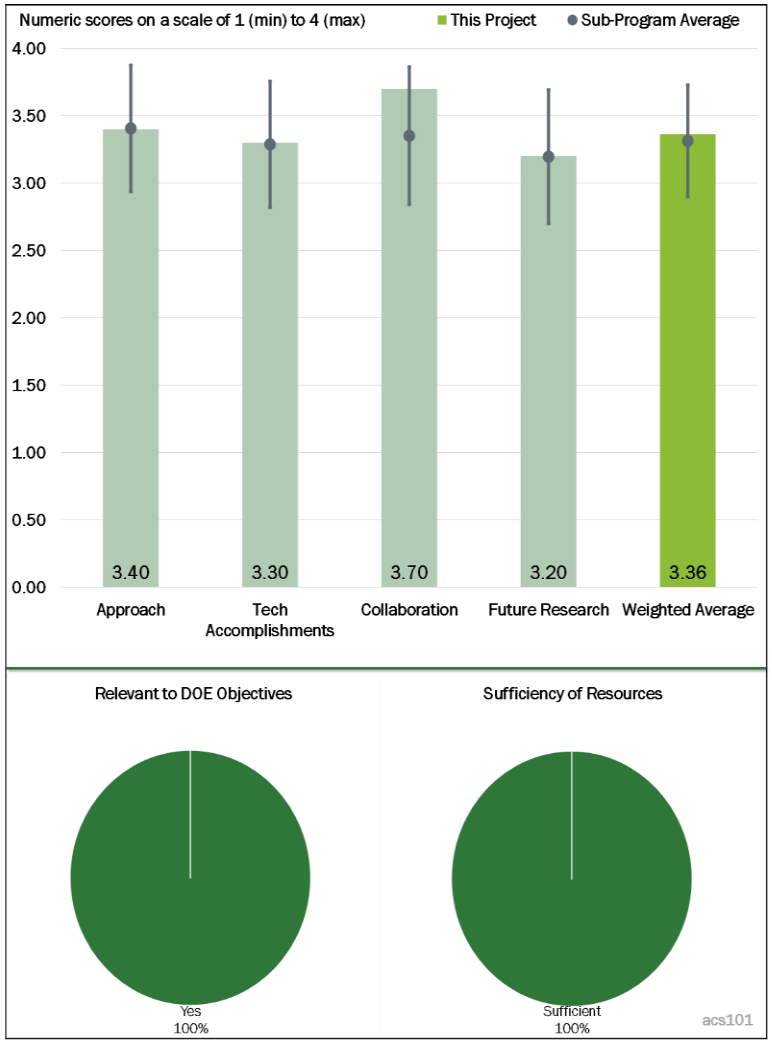

Figure 1-24 - Presentation Number: acs101 Presentation Title: Volvo SuperTruck II: Pathway to Cost-Effective Commercialized Freight Efficiency Principal Investigator: Pascal Amar (Volvo Trucks North America)

Presenter
Pascal Amar, Volvo Trucks North America

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
This reviewer appreciated the collection of fleet info and was especially impressed with the collection of off-highway use, which is suspected to be the main fuel usage. The lightweighting approach with durability testing is appealing. The reviewer highlighted that including overnight stays in the driving profile is great. For as long as this reviewer has been reviewing SuperTruck projects, this person has seen how much the aerodynamics has reached the highway. There is quite a lot.

Reviewer 2:
The reviewer noted this to be an excellent project looking at all salient aspects.

Reviewer 3:
The reviewer stated that this project has a solid approach. The PI referenced ST1 oftentimes proving that the author had ideas in that program without time or budget to enact them and are now doing so with ST2. This project is approaching commercial viability well. When the reviewer asked the PI how this was being done, the PI answered with “Creating models for TCO decisions by technology.” The reviewer remarked that this was well done and will look to see these next year.

Reviewer 4:
The reviewer observed that for the approach to vehicle configuration, the seemingly large effort going into data collection to map out the fleet driving cycle was a little surprising. The reviewer would have assumed that this was information that was already known to a major truck manufacturer. Perhaps something different was missing about this particular data collection, such as hotel loads. The rest of the approach is sound, except for

the continuation of the split-cycle engine. The reviewer was not sure what has been driving the continued interest in this technology.

Reviewer 5:

The reviewer commented that the approach for the vehicle mentioned in Slide 8 is too simplified, which only talks about fleet duty cycle creation. The reviewer mentioned that the technology road map includes many technologies. On the engine side, the reviewer was not sure how valuable the dual compression/expansion engine is. Even if it would work, which would be still a big "if," the reviewer questioned how this could be fit into the vehicle. Also, it seems that the concept of this engine could increase engine weight significantly according to the figure in Slide 23, which may eat up other benefits. The reviewer concluded that no plan is demonstrated that this engine can have a chance to be realized in the vehicle.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the aggressive approach to powertrain weight reduction is very impressive. The lessons learned here can be propagated forward in many applications. This work shows that there is significant fuel savings in "look ahead" driving strategies. The reviewer observed that the hotel cycles especially were thought through.

Reviewer 2:

The reviewer noted good progress on the tires, lightweighting, and aero for the truck are evident. Combustion, heat loss, and electrification all showed good accomplishments on the powertrain.

Reviewer 3:

The reviewer said that the project is making good progress on some very difficult key decisions and is using field data well.

Reviewer 4:

The reviewer remarked that the project is making very good progress with the project 35% complete. However, the project lead admits that the 55% BTE will not be achieved. The combustion work has led to unexpected/counterintuitive findings; however, these were not specified. The author mentioned that an empirical approach may be more useful than the simulations.

Reviewer 5:

The reviewer commented that no intermediate BTE progress is reported. Most of the work accomplished today was only planning and concept design. To a minimum, the progress has been specifically on the simulation side. On the advanced engine, it should be made in terms of BTE, if no testing is available at this time. The reviewer observed that no actual value can be appreciated with this new engine concept if it would not be fitted into a vehicle. If this is so, the reviewer suggested that resources are wasted on this engine.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer affirmed that project lead (Volvo) has been very proactive in defining and involving partners. For example, the weight reduction measures identified by Penn State collaborators are noteworthy.

Reviewer 2:

The reviewer stated that collaboration and coordination seem to be excellent, which the presentation shows in Slide 3.

Reviewer 3:
The reviewer noted very good collaborations shown on this project, and nicely summarized on Slide 3.

Reviewer 4:
The reviewer highlighted very strong assets of this team. The PI openly mentioned that the team has a unique, strong proposal from Bergstrom that they are very excited about. This is an example of collaboration versus "not invented here." The reviewer suggested that this team may have more of these examples.

Reviewer 5:
The reviewer reported that clearly there are a good range of partners. It was not clear to the reviewer which ones made major contributions and which were less impactful.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer observed that the future research is to keep on going and totally agrees with this.

Reviewer 2:
The reviewer noted a very strong plan exists for the rest of the project. The reviewer suggested planning on incorporating some cab changes.

Reviewer 3:
The reviewer commented on the aftertreatment system, describing that the use of a close-coupled SCR upstream of the filter may lead to the undesired consequence that passive regeneration cannot be accomplished. This can decrease efficiency by 1%. The reviewer requested that the project team please comment on this decision.

Reviewer 4:
The reviewer noted that not much time was spent on the future plans, so this was difficult to evaluate.

Reviewer 5:
The reviewer said that it would be much clearer if the presentation would be written in such a way that one or two separate slides would be dedicated to proposed future research, although some of the future plans can be seen in some of the individual slides.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted clear and obvious alignment with DOE objectives.

Reviewer 2:
The reviewer highlighted that especially relevant are the aggressive weight reduction technologies and the on-the-road adjustments of engine and driver strategies.

Reviewer 3:
The reviewer said that the project seeks to improve freight efficiency and engine efficiency, consistent with DOE goals.

Reviewer 4:
The reviewer remarked that Class 8 burns a ton of fuel and this team is committed to not only showing a ST2 with much better freight efficiency but spinning off ideas into production as quickly as possible.

Reviewer 5:

The reviewer stated that this program, if delivering, would definitely help the nation to reduce fuel consumption.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that resources were absolutely sufficient.

Reviewer 2:

The reviewer asserted that the team seems to be doing well with the present level of funding.

Reviewer 3:

The reviewer commented that the resources look to be in line with the work completed and proposed.

Reviewer 4:

The reviewer reported that the resources are sufficient.

Reviewer 5:

The reviewer commented that, with the vast past experience obtained from ST1, the project should have sufficient funding to complete the program

Presentation Number: acs102
Presentation Title: Cummins-Peterbilt SuperTruck II
Principal Investigator: Michael Ruth (Cummins-Peterbilt)

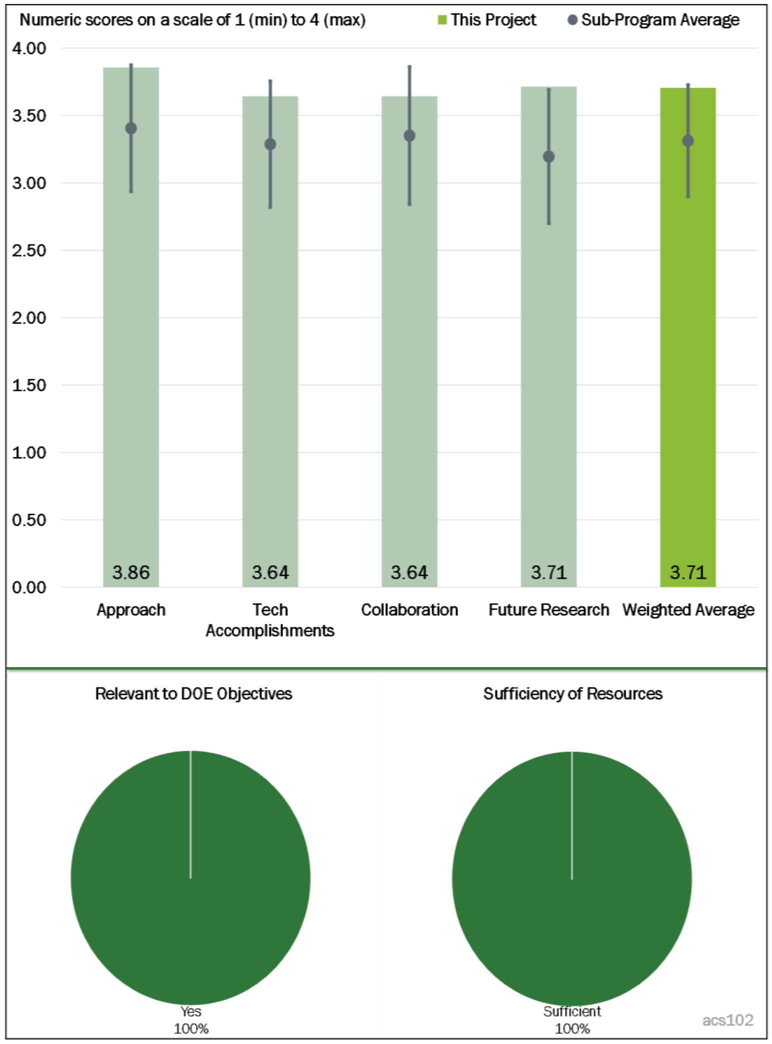

Figure 1-25 - Presentation Number: acs102 Presentation Title: Cummins-Peterbilt SuperTruck II Principal Investigator: Michael Ruth (Cummins-Peterbilt)

Presenter
Michael Ruth, Cummins-Peterbilt

Reviewer Sample Size
A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer could see no way to suggest improvements. The active yaw control is unique and makes great sense and, at present, is unique for this application. It also may be a safety feature in helping make the tractor-trailer system less susceptible to overturning during a catastrophic event. The reviewer observed that the other accomplishments are first-class also.

Reviewer 2:
The reviewer commented that the level of system integration across the entire vehicle is very impressive and well thought-out, down to addressing components which usually would be ignored. The project appears well-designed to address both the freight efficiency and engine efficiency goals.

Reviewer 3:
The reviewer stated that this was an outstanding project on all fronts.

Reviewer 4:
The reviewer noted that this is a very well thought-out set of technologies done by people who know the business and do good analysis and testing.

Reviewer 5:
The reviewer acknowledged an excellent approach on the trailer, tires, and aero. The Cummins Energy Recovery Drive with the waste head recovery integrated provides a novel packaging approach to the program.

Reviewer 6:

The reviewer remarked that the project had a very strong approach. The ST2 teams benefit in efficiency on these programs having completed ST1. This refines the approach and gets more done for the money, which is impressive.

Reviewer 7:

The reviewer offered that this is an outstanding program with very aggressive goals, but with a comprehensive plan to back up the claims. A complete new engine to support the program is a big plus together with their previous success from the ST 1 program. The reviewer noted that this was very well done, but it still remains to be seen whether it can really deliver.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that this ST2 project is clearly best of the best. All the other projects are focusing on individual parts of technology. Basically, this project has them all.

Reviewer 2:

The reviewer indicated that the quoted achievements to date are in line with what would be expected at this point in the program, and are well documented to demonstrate the progress.

Reviewer 3:

The reviewer noted progress has already been made on efficiency targets.

Reviewer 4:

The reviewer observed that this is impressive work. Both experimental and analytical methods are used and are well integrated. The reviewer concluded that very nice progress is reported.

Reviewer 5:

The reviewer affirmed that great progress is made in all areas of the engine and vehicle.

Reviewer 6:

The reviewer stated that it is an impressive design on this new engine/powertrain platform (Slide 11 and Slide 12). Excellent progress has been made (shown in Slide 13), but there is still some distance to go in meeting the 50% goal, but it should be on the way. The disengage-able tandem axle made this program more practical to deliver overall better performance even with 0.4% fuel economy improvement. The reviewer suggested that Slide 10 (ST 2 Target) as presented, is confusing. More description on this figure would be helpful. In addition, it would be more helpful if the path shown in Slide 21 includes clearer indication of the scale of BTE improvement.

The reviewer said that the progress on the vehicle side is also impressive. Weight reduction is aggressive (Slide 35). Although good progress has been made on the tire side, it is not clear why single wide base tire was not selected for this program, which does not make common sense. The reviewer offered that explaining this decision between single and dual tires would be helpful.

Reviewer 7:

The reviewer was a bit unsure about this project. It seemed to the reviewer that more evidence of progress on technical accomplishments could have been added here. It seems like there was a lot of effort on weight reduction and with only a few fleets able to really add payload. This may not be best in the long term.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that the team has organized an impressive set of partners and suppliers. All the important aspects of the program seem to have been worked on by experts who are doing their part, with effective coordination and collaboration.

Reviewer 2:
The reviewer noted that clearly the Cummins-Peterbilt collaboration is a partnership. Bridgestone has contributed well. Walmart is a great contribution to this program. It puts a real-world aspect into the driving profiles. The reviewer concluded that Eaton is good on transmissions.

Reviewer 3:
The reviewer observed involvement of a large and comprehensive group of collaborators.

Reviewer 4:
The reviewer remarked that Slide 5 shows strong collaborations with various partners.

Reviewer 5:
The reviewer acknowledges a great list of collaborators; however, it would be helpful to point out who is a supplier/vendor and who is a participating partner. Collaborator roles for some were pointed out in the technical accomplishments throughout the presentation, but only a handful of them were mentioned. The reviewer questioned what the rest are contributing.

Reviewer 6:
The reviewer commented that results from some of the partners in the team were called out and appears to be well integrated into the overall program plan. There were many more partners listed who did not have any documented activity in the presentation. It was unclear to the reviewer if this is because their contribution is called for at a different time or if the author was just not able to fit them into the presentation. It would be good to have a sense of what all the partners were doing given the huge list of them.

Reviewer 7:
The reviewer would like to see more work with end-user fleets. The reviewer suggested some sort of annual or biannual ST2 customer focus group. These teams are relying too much on in-house knowledge of customers' expectations.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the plan presented seems to be very well-thought through and will evaluate a very wide range of technologies, with an effective plan to develop the necessary data and downselect the right set of components. This is the way it should be done.

Reviewer 2:
The reviewer noted that a great pathway was laid out for reaching the program goals.

Reviewer 3:
The reviewer observed that finishing the project in all its aspects is clearly a great forward plan.

Reviewer 4:
The reviewer affirmed that there is a strong plan in place to finish this project.

Reviewer 5:
The reviewer stated that it does appear that the plans for future work are well-constructed to achieve the ST2 goals. It would be good to see some kind of efficiency waterfall plot to get a sense of the demands on each development in the plan and to see where uncertainty in the final performance would impact the path to the 55% BTE goal.

Reviewer 6:
The reviewer said that the plan forward was fine.

Reviewer 7:
The reviewer highlighted that the proposed future research that includes cost makes this program more practical. A few technologies on the powertrain side, including low-pressure EGR and mild hybrid system, are appropriate. The reviewer questioned why there is not anything related to combustion, WHR, and other technologies. One of the drawbacks on this presentation is that there is nothing mentioned on the vehicle side for the proposed future research.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted that this project is directly in line with the overall DOE objectives to increase energy efficiency and reduce petroleum consumption. It also seems likely to impact real-world fuel use based on the experience from ST1 and the technology transfer from the DOE program to production trucks.

Reviewer 2:
The reviewer observed that ST2 seems to be critical, and very relevant, to the DOE mission.

Reviewer 3:
The reviewer stated that this is a critical project to fulfill DOE objectives.

Reviewer 4:
The reviewer said that Cummins has already pushed some of the ST1 developments into production. If this continues then the relevance is obvious.

Reviewer 5:
The reviewer affirmed that the goals of improved engine efficiency and freight efficiency are well aligned with the DOE objectives.

Reviewer 6:
The reviewer remarked that for the United States to decrease fuel use and carbon dramatically, over-the-road tractors need to be addressed, and this project does that.

Reviewer 7:
The reviewer indicated that this program would certainly help to reduce imports and improve energy security.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer offered that there appears to be plenty of resources to perform the planned work towards the project milestones and end goals.

Reviewer 2:
The reviewer observed excellent facilities and resources.

Reviewer 3:
The reviewer commented that the resources seem to be both necessary and sufficient for a large program such as this one.

Reviewer 4:
The reviewer noted that when the components developed in a project are clearly market ready, then the funding is sufficient. The reviewer suspected that the partners long-term are getting much more out of the project than their individual contributions.

Reviewer 5:
The reviewer remarked that resources look appropriate for the work accomplished and proposed.

Reviewer 6:
The reviewer indicated that the resources appear sufficient.

Reviewer 7:
The reviewer said that the team’s past vast experience should help the program to complete in time and in the given resource.

Presentation Number: acs103
Presentation Title: Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer SuperTruck
Principal Investigator: Russell Zukouski (Navistar)

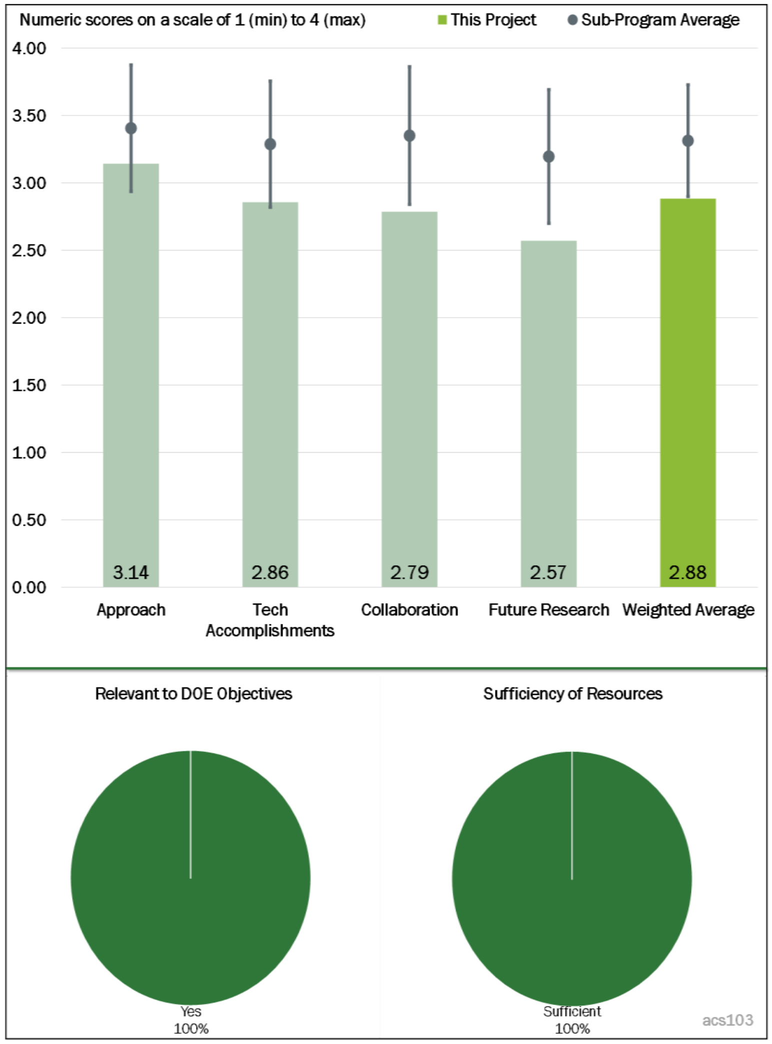

Figure 1-26 - Presentation Number: acs103 Presentation Title: Development and Demonstration of a Fuel-Efficient Class 8 Tractor and Trailer SuperTruck Principal Investigator: Russell Zukouski (Navistar)

Presenter
Russell Zukouski, Navistar

Reviewer Sample Size
A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer commented that the project is well-configured to address the technical challenges associated with achieving the freight and engine efficiency improvements of the ST2 program.

Reviewer 2:
The reviewer noted that the project was overall well-planned with a clear approach to achieving goals for engine and vehicle. As a modest weakness, the GCI side project seems just that, a project on the side, maybe as a contingency in gasoline in case the core diesel plus aftertreatment path has an issue.

Reviewer 3:
The reviewer remarked that the project generally had a good approach. The reviewer was not clear how the ANL GCI work fits into SuperTruck.

Reviewer 4:
The reviewer indicated that the approach is strong for success. The reviewer would like to see more work/engagement with end-user fleets. The project is currently relying too much on in-house expertise.

Reviewer 5:
The reviewer stated that the thoroughness evident in the other ST2 projects was not as apparent with this project.

Reviewer 6:

The reviewer observed that this is mostly a planning project that is well behind all the other programs. There is no indication of what electrification system will be used. There is no evidence that the compression ignition technology will work. The reviewer believed that a report from ANL would have been very helpful. The reviewer commented that the project had nice work on the drivetrain axle. The aerodynamics work is pretty consistent with all the other competitors. It probably means that the solutions are obvious. The reviewer could not tell what the exhaust temperatures are predicted to be. Gasoline exhaust is typically higher than diesel. An electrically heated catalyst might be energy efficient.

Reviewer 7:

The reviewer observed that the technical approach shown in Slide 5 included all key technology components except tires. It is hard to understand why tires would not be part of the key technology package. In addition, the reviewer proffered that it would be helpful to be more specific in terms of relative scale. Just from this figure (Slide 5), it seems that WHR is so critical, taking more than 50% contributions to achieve 55% BTE, which makes the program too risky if WHR cannot achieve the target goal.

The reviewer further commented that with limited resources, it is not clear whether a second engine with GCI concept would be a smart choice to study. Because there would be only one engine that can be installed in the vehicle, it is a high risk to divert funding on a high-risk engine, where the limitation on this engine would be high loads for on-highway application.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed that the team has made solid progress on the key engine and vehicle subsystems. The engine subsystems include air handling, fueling, WHR, etc. Vehicle tractor-trailer coupling to enhance the integrated aero package is noted. On the vehicle system, electrification is shown as having a 2% benefit. Hybridization is noted as “double-digit” impact. The reviewer recommended that a more precise estimate for certain drive cycles would have been welcomed, or else discussion why an estimate was not ready.

Reviewer 2:

The reviewer stated that the project had good progress. The reviewer would like to see more evidence of using commercialization criteria on decision making.

Reviewer 3:

The reviewer commented that the progress seems okay. Most of the stated activity appeared to have some forward motion but most tasks also seemed to have not fully achieved the goal of each task. While it is still reasonably early in the project, it would be nice to see how the results to date impact the team’s assessment of their progress towards the final program goals.

Reviewer 4:

The reviewer said that the author reported many progresses, but they are largely analytical. The author reported no progress on the tire side, which should be one of the critical parts of this program. This is one of the biggest drawbacks of this program. The reviewer remarked that it is too vague to mention that “a compound system has been identified” of WHR in Slide 8. The reviewer questioned what that was.

The reviewer also commented that it is not clear how this GCI engine has more potential to achieve 55% BTE goal than the conventional engine, according to Slide 9. Even if it does, the reviewer wondered if there is any possibility for vehicle demonstration. Again, using two engines for this program would be too risky and may end up as a total waste considering the limited funding.

Reviewer 5:
The reviewer warned that the accomplishments are lagging in this project. There is much work to be done.

Reviewer 6:
The reviewer noted that there was not much real data presented.

Reviewer 7:
The reviewer said that only 20% completion seems to be significantly less than the other ST2 projects.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that the project has strong teamwork. The reviewer would like to see end users more apparent and involved. The reviewer proposed an ST2 annual or biannual focus group meeting.

Reviewer 2:
The reviewer noted that the project teaming arrangement looks good for achieving the goals, but it is not clear at all from the presentation how much the team is working with Daimler and how much is its own.

Reviewer 3:
The reviewer indicated that the team members mostly appear to have direct input to the final goals and vehicle prototype. The exception may be the ANL engine project, where it is unclear what outcomes or data will be used in the final vehicle or 55% engine.

Reviewer 4:
The reviewer noted that there are major expectations for the partners to make this project successful; however, there were no reports from the partners on the progress of the partners.

Reviewer 5:
The reviewer said that there was good collaboration with suppliers. However, the reviewer did not see a trailer maker involved in the major program work. Integration of cab, engine, and trailer seems to be critical in these ST2 projects.

Reviewer 6:
The reviewer said that Slide 3 well defines the role of each team member to play, but having no tire partner is disappointing.

Reviewer 7:
The reviewer observed that the lack of a fleet partner on the team may be an issue.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the plan to deliver seems strong.

Reviewer 2:
The reviewer asserted that the presentation lacked clarity on future research, with next steps being spread throughout many pages. Those various items were okay when found. The future of the all-important WHR system needed more discussion.

Reviewer 3:

Generally, the reviewer described the plan as okay. However, the reviewer would like to see the team clarify whether and how the ANL GCI work fits, and how selection will be made for the final project. As the reviewer understands it, the program metrics are based on highway 18-wheeler operation. If GCI is used in a multimode system, the reviewer questioned how often it will be used. The reviewer wondered if there is a plan to develop mode switching and real-time optimization. Regarding the effects of fuel, the reviewer questioned if a dual-fuel system is required and if so, if it is customer acceptable and cost effective. In the reviewer’s experience, many truck stops have diesel and gasoline at completely different fuel islands and that might be objectionable to the drivers if both are needed.

Reviewer 4:

The reviewer noted that the future research is all with the partners. No real information was presented.

Reviewer 5:

The reviewer remarked that there really was not any discussion of the future research or how the results to date are changing the plans for the next FY of the program.

Reviewer 6:

The reviewer observed that no details were provided.

Reviewer 7:

The proposed future plan is too simplified, which is shown in Slide 17.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer noted that the project pushes the state of the art forward, and supports DOE’s mission in energy efficiency and competitiveness in vehicles.

Reviewer 2:

The reviewer offered that the project is aligned well with DOE objectives.

Reviewer 3:

The reviewer commented that ST2 seems to be very central to the DOE mission.

Reviewer 4:

The reviewer said that this program will significantly reduce fuel consumption, which should support the overall DOE objectives.

Reviewer 5:

The reviewer noted that fuel use is high for Class 8 over-the-road vehicles and this segment must be addressed aggressively.

Reviewer 6:

The reviewer remarked that if successful, the project will achieve DOE goals of reducing petroleum consumption and increasing transportation efficiency.

Reviewer 7:

The reviewer noted that if successful it will move some of the Class 8 fuel consumption from diesel to gasoline. That is a mixed blessing. The value of that will depend on the most efficient hydrocarbon mix from the refiners.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer acknowledged that ST2 projects are quite large and long-duration. The resources seem adequate and appropriate.

Reviewer 2:

The reviewer said that the resources appear sufficient.

Reviewer 3:

The reviewer reported that there appears to be adequate funds for a successful program. It is a bit hard to track if the work to date aligns well with the funds expended and the glide slope towards the project end goals.

Reviewer 4:

The reviewer stated that, considering the breadth of the development of technologies and the final field tests, the resources are just adequate and only with the cost share.

Reviewer 5:

The reviewer had no idea if the partners are cash strapped or not.

Reviewer 6:

The reviewer noted that it was unclear what facilities are available for emission control systems.

Reviewer 7:

The reviewer suggested that the program should focus on one main engine platform. Diverting the funding on two engines would risk the program funding sufficiency.

Presentation Number: acs116
Presentation Title: Advanced Non-Tread Materials for Fuel-Efficient Tires
Principal Investigator: Lucas Dos Santos Freire (PPG Industries)

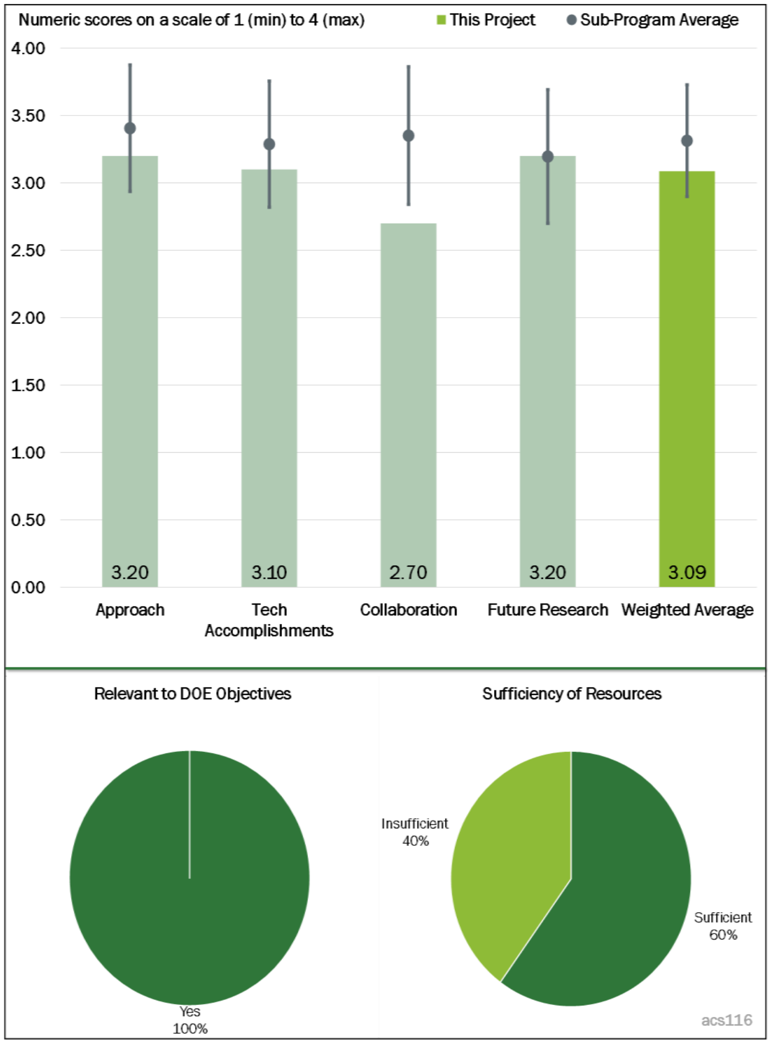

Figure 1-27 - Presentation Number: acs116 Presentation Title: Advanced Non-Tread Materials for Fuel-Efficient Tires Principal Investigator: Lucas Dos Santos Freire (PPG Industries)

Presenter

Lucas Dos Santos Freire, PPG Industries

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that tires provide a lot of payback in terms of fuel efficiency. This is a viable approach.

Reviewer 2:

The reviewer commented that a good approach was seen. Groups with solid knowledge have defined an important area of work and opportunity.

Reviewer 3:

The presented approach to this project looked sound and thorough.

Reviewer 4:

The reviewer indicated that while there is merit to giving attention to sidewall materials and not just tread materials, doing so somewhat independently instead of as a system, and proceeding without integrated involvement of a tire manufacturer, appears risky and suboptimal.

Reviewer 5:

The reviewer stated that the approach is systematic, but the underlying reasons for selecting the approximately 10 different fillers were not articulated. This comes across as being somewhat Edisonian. Also, the different tests were not defined in terms of why these collectively comprise the criteria for optimizing the compound. The reviewer suggested that a better case could have been made on why the tests selected are relevant. If these are well-accepted by the industry, then say so. The reviewer concluded that the presentation was overall uninspiring.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed that the team has made excellent progress on reducing the tan delta of materials along with researching other critical properties. The metric of tan delta is more subtle than the coefficient of rolling resistance (Crr), the later used much in describing the characteristics of complete tires. The project accomplishments would be clearer if related to Crr.

Reviewer 2:

The reviewer characterized the progress as excellent so far. It will be good to see work with a tire company and a real tire result.

Reviewer 3:

The reviewer noted that it seems that quite a lot has been achieved, but it is difficult for this reviewer to understand the pathway that leads to the end goal.

Reviewer 4:

The reviewer commented that it is not clear from the presentation what the metric for improvement is. Additionally, there is no comparison with present sidewall products. Slide 15 comments on this, but it has very inadequate information.

Reviewer 5:

The reviewer reported that the compound results do not show a sample that meets all four goals (Slide 10), at least before compound adjustment.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that PPG has an excellent partner with Akron Rubber Development Laboratory (ARDL) with a lot of expertise in this industry. The reviewer encouraged the project to consider additional partners, like universities, although the reviewer acknowledged that this project does not have a large budget.

Reviewer 2:

The reviewer really wishes that this work was integrated with the major tire manufacturers. It would help to ensure any major accomplishments would be incorporated into future products.

Reviewer 3:

The reviewer suggested that the project would be stronger if one or more tire companies were fully integrated with the team. The support letters helped to justify a satisfactory score.

Reviewer 4:

The reviewer indicated that the collaboration aspects were not articulated. The ARDL was mentioned but their contribution is unclear to date.

Reviewer 5:

The reviewer said that this project will be better with one or more tire companies in the future.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the future research seems adequate as there is convergence to a final compound.

Reviewer 2:
The reviewer observed that this seems like a good approach, developing the materials with laboratory tests, and eventually building tires for testing.

Reviewer 3:
The reviewer reported that the team has identified the key points for future research. The reports cited that explain the relationship between tan delta and rolling loss coefficient are not really adequate. It may be more straightforward just to add a slide discussing this fundamental visco-elastic characteristic. The reviewer further noted that gaining the interest of a tire company is essential, and this process was not described well.

Reviewer 4:
The reviewer offered that there should be a cost analysis included.

Reviewer 5:
The reviewer asserted that not a lot of detail was presented for future research, nor could it be found in the reviewer only slides. More information would have helped understand how the remaining barriers will be overcome.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted that this project addresses the DOE objective to reduce fuel consumption for transportation vehicles. It would be applicable across all vehicle types, so potentially could have a big impact.

Reviewer 2:
The reviewer said that this project was relevant because of focus on fuel economy improvement.

Reviewer 3:
The reviewer commented that improved rolling resistance will improve efficiency and that fits DOE goals.

Reviewer 4:
The reviewer indicated that the tire manufacturers have made great strides in improving the fuel efficiency of the vehicles. The reviewer admitted not being well informed what specifics Bridgestone or Michelin are addressing, so it is not known if this is redundant. The reviewer agreed that sidewalls are a big contributor.

Reviewer 5:
The reviewer asserted that rolling losses are highly relevant to trucks and passenger vehicles. The reviewer recognized that significant progress has been made in last 15 years, but tradeoffs remain with wet traction and wear.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that PPG is well equipped to carry out the materials evaluations.

Reviewer 2:
The reviewer observed that until the project scales up to prototyping full tires, the resources are reasonable.

Reviewer 3:
The reviewer remarked that, not knowing how much laboratory development and testing costs, it seems like the resources are probably sufficient.

Reviewer 4:
The reviewer stated that it is not clear from the lack of a cost analysis and the lack of a large-scale tire manufacturer whether this project needs additional funds to get to implementation. This project has very limited value if there is no clear plan to reach implementation.

Reviewer 5:
The reviewer commented that the budget on this project seems quite low for the amount of effort and the barriers it is trying to overcome.

Presentation Number: acs118
Presentation Title: Advanced Emission Control for High-Efficiency Engines
Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

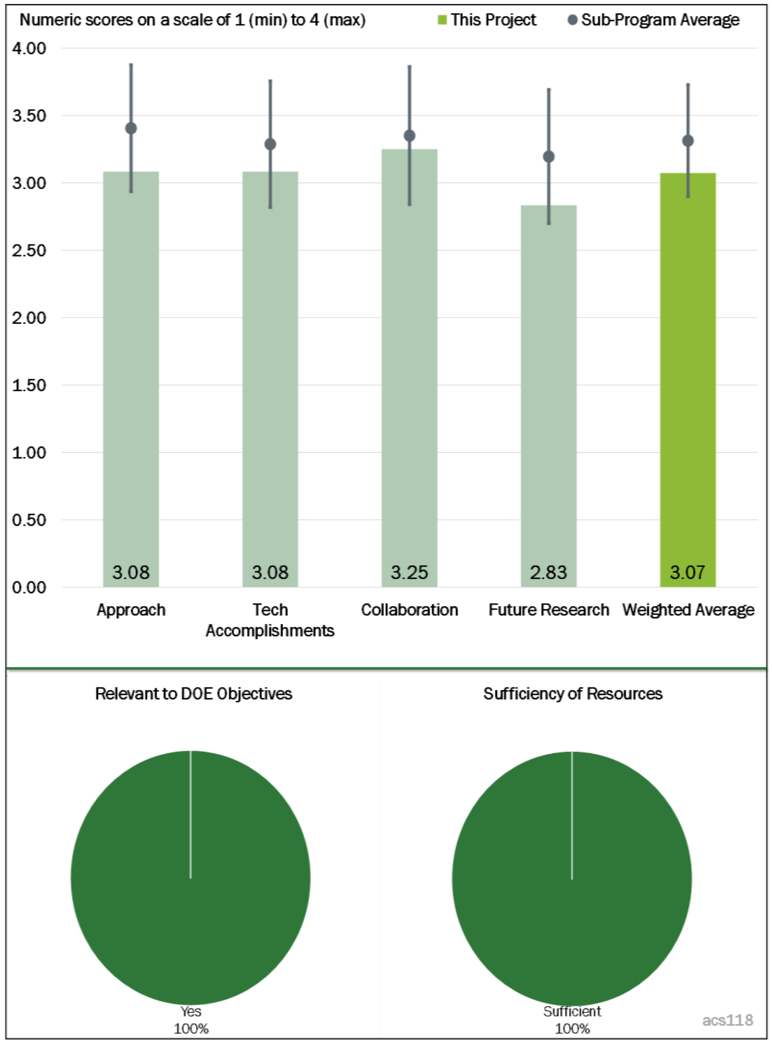

Figure 1-28 - Presentation Number: acs118 Presentation Title: Advanced Emission Control for High-Efficiency Engines Principal Investigator: Yong Wang (Pacific Northwest National Laboratory)

Presenter

Yong Wang, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer appreciated that the project team was willing to adjust the scope based on reviewer feedback. It looks like catalyst characterization work at PNNL is the most prominent part of the work.

Reviewer 2:

The reviewer stated that it appears that the PNNL group has reduced their scope to better align resources with desired, emerging catalyst technologies. This is more desirable from a reviewer's point of view. This year's update reinforces this approach on two very important forward-looking technologies, which are PNAs and compressed natural gas (CNG) catalysts. With respect to PNAs, continuing their effort to understand the uptake and release mechanisms to optimize the material is important. New insight is also gained from their work with different pore size and form of support. The reviewer further indicated that including work to understand deactivation mechanisms is required to determine the limitations of new materials at an early stage so that there is time to redevelop a technology pathway. Regarding CNG catalysts, although this is addressing the administration's interest in CNG vehicles, the reviewer asserted that most of the OEM community is not in agreement and is not dedicating resources to this area of research.

Reviewer 3:

The reviewer noted that this project has good work. It focuses heavily on the fundamentals, and has looked effectively into aging and palladium dispersion impacts, amongst others. It is nevertheless concerning to the reviewer to see that other fundamental considerations such as impact of HC (or S) are considered "future work" on the 9th year of this study. Instead it is something qualifying that should have been instead in the initial blueprint. The reviewer questioned what is meant by "Study the effect of other gaseous exhaust emission component gases on the performance of PNAs" (stated in Future Work). Specific gaseous species should be further specified, and the reviewer suggested that more specifics are heavily warranted, especially given that there is only 1 year left to the termination of the project. Despite its beauty, the reviewer stated that the work appears to be harmed by two things (i.e., suboptimal priorities and lack of specifics).

Reviewer 4:

The reviewer observed that detailed characterization using Fourier transform infrared (FTIR), extended X-ray absorption fine structure (EXAFS) and X-ray absorption near edge structure successfully revealed the nature of Pd/zeolite catalysts and the mechanisms involved in NO_x storage in zeolite-based PNAs. However, one critical issue associated with current PNAs is premature release of stored NO_x before reaching the light-off temperatures of SCR catalysts. This issue becomes even more serious after aging. Thus, the reviewer noted that it seems desirable to focus on release characteristics (rather than storage phase as in the past) to determine the controlling factors for the release of storage NO_x from current PNAs and what can be done to modify/improve the release properties, especially after aging.

Regarding the modes of catalyst aging, the reviewer highlighted that a brief exposure to fuel-rich gaseous streams has been observed to be particularly detrimental, and thus is worth considering (in addition to usual HTA) for catalyst aging studies.

The reviewer believed that the reported effects of varying the silicon/aluminum (Si/Al) ratio on Pd dispersion and NO_x storage capacity are interesting observations, but may have limited practical significance/value because zeolites with high Si/Al ratios are generally favored for automotive applications. This is because of their better hydrothermal stability and their effectiveness at mitigating the H_2O inhibition of NO_x storage behavior.

The reviewer observed that this project proposed to investigate both PNAs and methane (CH_4) oxidation catalysts, but there seems to be no obvious synergy between them (although there are literature reports that zeolite-based Pd can be a promising CH_4 oxidation catalyst).

Reviewer 5:

The reviewer noted that vehicular catalysts face extremely harsh conditions, including high temperatures, significant water content in the exhaust flow, S and other poisons in the gas flow, and have a requirement for very long durability at these conditions. A minimum pretreatment for a possible automotive catalyst is 10 hours with steam at 700°C -800°C. This causes severe loss in dispersion, typically a loss of about 90%. The loss over 10 hours is effectively exponential. That loss of dispersion indicates a change in morphology into a phase, which has sufficient stability to retain its activity through the government mandated mileage.

The reviewer further highlighted that the 300°C calcination used in the work up to now is not sufficient to cause this possible morphology change. Suppliers typically do not bother to investigate any new material until it has gone through this stringent aging. Since, in general, the pretreatment of each of the samples is not provided, it is difficult to know if the catalytic material has been sufficiently pretreated to indicate whether it is interesting. The reviewer said that Slides 7, 8, 13, and 14 are good, but questioned if Slides 9, 10, and 11 are fresh only. The reviewer was not certain what the x-axis is on Slide 12.

Reviewer 6:

The reviewer said that feedback from last year suggested a change in the approach, which has been mostly met. Dropping the PM work to focus on PNAs makes sense due to the needs of industry. However, the reviewer suggested that the team focus on aging and poisoning, and while there has been work on HTA, there has been relatively little work on the poisoning. The reviewer concluded that the areas of focus still seem to lack synergy.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer stated that continuing to develop PNA materials that show very good update and retention of NO is very important for addressing the need for LTAT solutions. The reviewer acknowledged very impressive NO_x storage capacity. Continuing to optimize the capacity and release conditions is appropriate. Just as important are their characterization studies to obtain more insight into the material qualities and how to exploit these properties. However, the reviewer highlighted that PNAs must be made robust enough to withstand HTA conditions that will be present in automotive exhaust systems. If they fail at lower temperatures, it is not a viable product. The reviewer concluded that more consideration should be given to this and other deactivation mechanisms.

Reviewer 2:
The reviewer stated that it looks like the project is meeting its milestones as planned, with both the PNA and the CH_4 oxidation catalyst. The reviewer highlighted nice results with the PNA materials characterization, especially as the materials are aged.

The reviewer understands the interest in determining which support properties influence CH_4 oxidation, but the use of SSZ-13 zeolites confounds this work with the PNA work, especially if the team does not expect an SSZ-13 support to be suitable for commercial CH_4 oxidation catalysts.

Reviewer 3:
The reviewer commented that there is certainly progress toward the key goals, although it is not hard to argue progress could have been a bit faster, especially if the team tackled more elementary considerations essential for practical PNA performance in real-world applications.

Reviewer 4:
The reviewer noted that good progress in providing fundamental understanding of NO_x storage in PNAs, but not enough results yet on CH_4 oxidation.

Reviewer 5:
The reviewer could not extract from the presentation the specific history of the sample before it has been tested, and therefore could not decide if the sample has useful information. Certainly, the dealumination is a recognized degradation process and does affect the dispersion, but there is an accompanying sintering that cannot be identified in this presentation. The reviewer observed that Slide 21 is helpful.

Reviewer 6:
The reviewer referenced prior comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that partnering with a supplier that is actively developing this type of PNA is very appropriate. Coupling the supplier's formulation capability with the testing and characterization abilities of PNNL is an excellent combination of resources.

Reviewer 2:
The reviewer stated that it looks like the project benefits from the capabilities and strengths of each project partner on the team.

Reviewer 3:

The reviewer remarked that Cummins and JMI are on-board with PNNL on this project. While it is true that PNNL has unique characterization tools, it is fair to think that the team would have benefited from synergizing additional know-how from having onboard university experts (e.g., University of Michigan, University of Houston, University of Kentucky, or others) familiar with both this technology's fundamentals and the industry needs. The reviewer noted that this would alleviate some of the progress challenges observed, hindering a better, faster progress.

Reviewer 4:

The reviewer observed that, while there is good collaboration between the national laboratory and industry on this project, there seems to be no university involvement in the project. The reviewer would like to see university collaboration included in the project.

Reviewer 5:

The reviewer offered that certainly Cummins and JMI should have similar concerns or they had more information.

Reviewer 6:

Given that this project is in the final stage (ending March 2019), the reviewer did not see evidence of significant participation/contribution by Cummins (or JMI) for possible engine testing. Such collaboration is not included in the Proposed Future Work (Slide 18) either.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted that the focus on deactivation mechanisms for future work is very appropriate. However, the reviewer said that an indication of these effects should be performed at an earlier stage so that inappropriate technologies are not advanced in the development process. CNG catalysts are a lower priority and resources should be minimized in favor of PNAs and SCRs.

Reviewer 2:

The reviewer remarked that it looks like the CH_4 oxidation catalyst work on this project is complete. It seems to the reviewer like the PNA durability work overlaps with other DOE-funded PNA development projects. The reviewer questioned how this scope is unique within the portfolio of DOE projects looking at PNA systems.

Reviewer 3:

The reviewer stated that some ambiguities exist in the "Future Work," e.g., "studying effects of their gaseous species on PNA performance." The reviewer requested more specification of "other species." Slide 17 states, "e.g. hydrocarbons." The reviewer wondered if that could have been water content or HC only. These are just examples. The reviewer wondered why "e.g." and that far more clarity is warranted.

Reviewer 4:

The reviewer reported that there appears to be no plan to do full-size catalyst preparation and/or engine testing on some promising candidate catalysts.

Reviewer 5:

The reviewer is looking forward to the S work.

Reviewer 6:
The reviewer observed that HTA is not directly addressed until the summary slide. Dealumination is a different process from sintering. The reviewer would like to have some way to distinguish the two in the future work. The investigators seem to recognize this distinction; however, the reviewer could not see anything in the future work that is an attempt to make this distinction.

The reviewer would really like to see the dependence of the Al sites on aging duration, and also would like to see what the increase of palladium oxide is versus aging time. The reviewer questioned if there is any information on the sulfur build up in the zeolite. The reviewer was not sure that the density functional theory has value in this.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that this project aims at providing promising low-temperature emission control technologies, a critical enabler for high-efficiency engines, including CNG vehicles.

Reviewer 2:
The reviewer said that, yes, this Cummins-driven CRADA supports DOE objectives.

Reviewer 3:
The reviewer commented that both the PNA and CH_4 oxidation catalyst development work support DOE's objectives of improving the efficiency of internal combustion engines.

Reviewer 4:
The reviewer asserted that LTAT catalyst technologies must be exploited to support OEM needs to introduce highly efficient powertrains that are capable of meeting emissions standards. Most challenges occur in the cold start and colder portions of the drive cycles used to validate emissions compliance. These lean technologies address this need along with SCRs.

In response to questions on lack of resources to cover all the activities, the reviewer highlighted that PNNL is focused on only two projects, PNAs and CNG catalysts.

Reviewer 5:
The reviewer observed that the project has certainly targeted DOE's main objective. It could have produced more breakthroughs however given the project duration and the funding size. Though the challenge appears to have been too broad of an initial scope, the reviewer offered that the project could still benefit from further "refining" its objectives.

Reviewer 6:
The reviewer remarked that, at this point, there are enough holes in this work regarding the history of the samples that it is not going to engender outside research. The reviewer requested that the team disseminate sufficient information to start some other studies.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that resources and funding appear to be sufficient.

Reviewer 2:
The reviewer commented that resources seem sufficient.

Reviewer 3:

The reviewer indicated that the project seems to have sufficient resources for conducting fundamental studies on catalytic materials and chemistry, as in the past, but full-size catalyst preparation and engine testing, if planned, would require significantly more resources.

Reviewer 4:

The reviewer observed that, with the CRADA cost share from Cummins, this project appears to be appropriately funded for its goals, especially with the adjusted focus to PNA and CH_4 oxidation only.

Reviewer 5:

The reviewer noted that, pursued at PNNL's unique laboratory capabilities, the project appears to have enjoyed sufficient resources. It is, however, planning, timeline, focus, know-how management, priorities, and execution which appear to have hindered stronger progress.

Reviewer 6:

The reviewer affirmed that, until there is a clear focus on the application, the reviewer views this project as excessively funded.

Presentation Number: acs119
Presentation Title: Development and Optimization of a Multi-Functional SCR-DPF (Diesel Particulate Filter) Aftertreatment System for Heavy-Duty NO_x and Soot Emission Reduction
Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

Presenter
Ken Rappe, Pacific Northwest National Laboratory

Reviewer Sample Size
A total of seven reviewers evaluated this project.

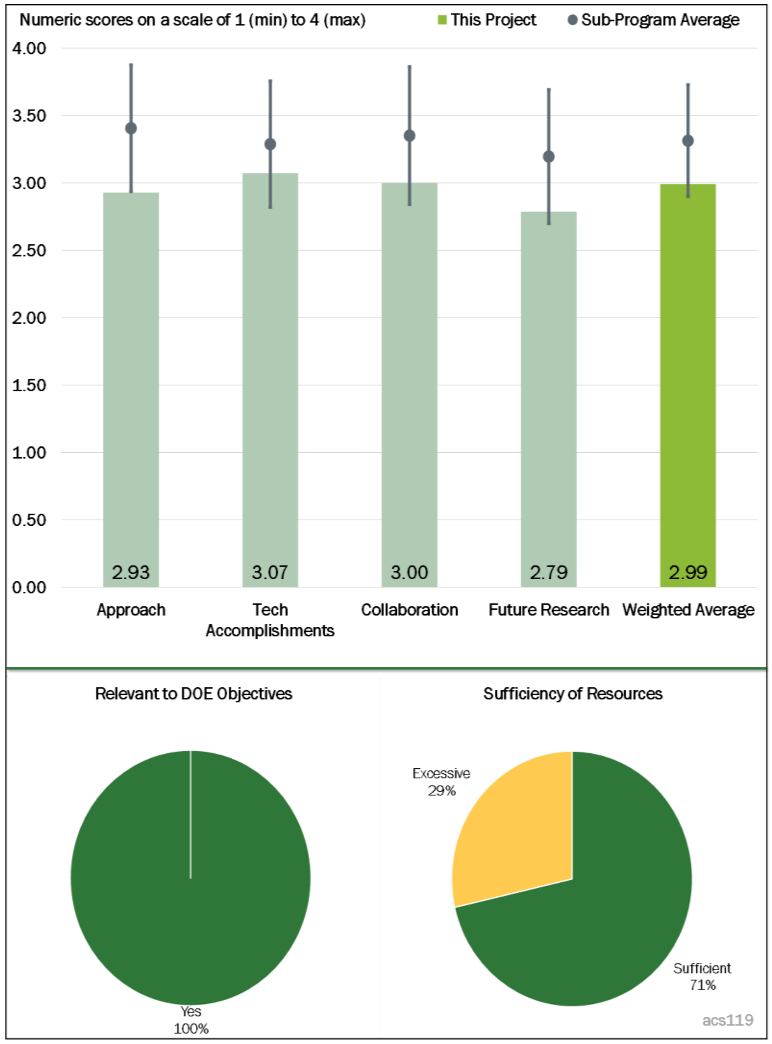

Figure 1-29 - Presentation Number: acs119 Presentation Title: Development and Optimization of a Multi-Functional SCR-DPF (Diesel Particulate Filter) Aftertreatment System for Heavy-Duty NO_x and Soot Emission Reduction Principal Investigator: Ken Rappe (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer stated that the development of multifunctional catalysts is an important area of research to minimize the packaging requirements of OEMs, while improving system performance by more closely coupling the aftertreatment to the engine. The concept of washcoating a DPF with SCR material is a practical extension of the need addressed above. Although this is not a new idea, incorporating additional washcoat components to improve the NO_x and particulate number (PN) function of the catalyst is a desirable feature that also increases the SCR volume for NO_x control. The reviewer also commented that incorporating selective catalytic oxidation (SCO) components into the washcoat is a logical and appropriate addition to the development process.

Reviewer 2:
The reviewer observed that the shared approach seems fine, although it is not clear how much direct interaction there is between PNNL and PACCAR.

Reviewer 3:
The reviewer noted that this project shows the impact of bromine (Br)/ZrO_2 and SCO on a combined SCR plus DPF performance. The reviewer appreciated this good work. It, however, at least as apparent from the presentation, appears “fragmented.” For instance, while it is stated that adding ZrO_2 assists with high temperature selectivity, nothing is shown as the end impact on the temperature-dependent soot. The NO_2

reaction is also in the same setting. The reviewer suggested that descriptions (if not charts) could have clarified this.

Reviewer 4:

The reviewer remarked that when SCR and DPF functionalities are integrated into one device (SCRF), SCF performance characteristics are affected by many factors, such as the presence of soot near the SCR catalyst, a limited amount of SCR washcoat in the pores in the substrate wall, and competition for NO_2 between the fast SCR and passive soot oxidation reactions. The relative importance of these factors needs to be assessed and quantified for optimizing the integrated unit.

The reviewer commented that it appears that the approach taken here focuses only on the last factor related to NO_2 availability for the fast SCR versus passive soot oxidation reactions. However, it is not clear whether this has proven to be the most important issue (or the most critical limiting factor) in determining the performance of the SCRF. Because the soot tends to accumulate near the mouth of the pores within the substrate wall of the SCRF, NO_2 would be in contact with the soot first, thus being consumed for soot oxidation before the SCR reaction as in the current aftertreatment system, where a DPF is located ahead of a SCR catalyst. This leads the reviewer to question the validity of the "competition for NO_2" argument illustrated at the bottom of Slide 4.

The reviewer suggested checking the validity of this premise by examining how the NO_x SCR, and soot oxidation performances are affected when NO_2 is added to the gas stream from a gas bottle. Also, if it turns out that more NO_2 is indeed needed to improve/optimize the SCRF performance (especially passive soot oxidation), it is not clear why more NO_2 should be generated over the SCR catalyst, as this project is trying to accomplish. The reviewer questioned the plausibility of modifying diesel oxidation catalyst formulations to generate more NO_2. In fact, NO_2 generated from the SCR catalyst may/may not provide enhanced passive soot oxidation in an effective manner because it would require back diffusion of NO_2.

Reviewer 5:

The reviewer acknowledged that introducing a new type of material, such as metal-oxide component, into this program would be something new and interesting, which clearly has some advantage in improving high temperature selectivity, thus improving performance and durability. However, the reviewer inquired about low-temperature performance for the cold start, and whether this system can meet emissions standards. In addition, the approach seems only to address the interaction between the fast SCR reaction and soot consumption with NO_2 (Slide 4). The reviewer suggested including the standard SCR reaction, because it would consume NO_2 as well, even though the timescale may be different between the fast and standard SCR reactions.

Reviewer 6:

The reviewer commented that this project seems to go down every rabbit hole that pops up. There is a lack of a goal-driven approach.

Reviewer 7:

The reviewer observed that this project has been ongoing in some form or another since 2010/2011, and yet there seems to be little progress. The reviewer questioned the approach and the continuation of this project and pointed out that the project team even agreed with previous reviewer comments that the approach is naive, difficult, and unlikely to be successful.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer offered that good progress has been made on SCR catalyst modification to increase NO_2 production via selective oxidation of NO.

Reviewer 2:

The reviewer stated that the zirconia attachment to the zeolite framework is especially interesting.

Reviewer 3:

The reviewer said that significant characterization of the SCRF catalyst has occurred in this project. The inclusion of barium (Ba) for additional NO_x storage, SCO for NO oxidation, and ZrO_2 as a way to stabilize the catalyst and improve the NO_x and NH_3 reactions are all logical extensions of the base work and should be pursued. However, the reviewer offered that more consideration should be given to the effect of the washcoat on backpressure and overall system response. Additionally, packaging considerations will have to be given consideration in conjunction with the amount of volume that will be needed when using lower loaded SCR components that are present in filters.

Reviewer 4:

The reviewer stated that it appears that the project team is making progress against the agreed milestones, although the one go/no-go gateway has been delayed from February 2018 to summer 2018. Focus is on SCR on DPF for HD applications, especially where there need to be differences from similar LD applications. The reviewer indicated that an interesting result was that so-called impregnation of CuO into the ZrO_2 matrix formed a new species phase. Also, it was interesting to the reviewer to see how adding Ba to the zirconia improves the NO_x conversion, especially the identification of the aging mechanism that affects low-temperature activity.

The reviewer reported that it was good that the team has been looking at catalyst durability, especially with respect to aging. The reviewer requested the project please provide details on how PACCAR is coating the SCR-DPF systems, because it is relevant to what DOE is funding.

Reviewer 5:

The reviewer commented that progress has been made. Though the idea of using Ba/ZrO_2 is interesting, what is shown is necessary information, but is not sufficient to make a convincing case. For instance, it is well-known that Br is sensitive to S deposit; nothing is said about this. Slide 11 on step mechanisms of reactions (NO to NO_2 conversation in fast SCR) is from Tronconi, but the source is not cited/given credit.

Reviewer 6:

The reviewer highlighted that progress has been overall slow, and there continues to be delays (February 2018 go/no-go decision). It is hard to imagine that significant progress or accomplishments will be achieved on this project. The reviewer observed evidence of “CLEERS work” mixed in, noting several similarities with ACS023. In addition, there is some very fundamental work going on that it is not clear how it is relevant or translates to the CRADA work.

Reviewer 7:

The reviewer said that it seems that progress has been made on the high-temperature side. However, the reviewer noted that the low-temperature side seems to face some issue (Slide 12), which would be one of the major issues to meeting standards, specifically the cold FTP cycle. It was not clear to the reviewer how the authors would handle this major low-temperature issues moving forward. It would be more helpful if the authors can address this issue even with a plan.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the role between PNNL and PACCAR has been clearly defined, and the collaboration and coordination between these two partners seems to be good.

Reviewer 2:

The reviewer remarked that the interaction with PACCAR seems to be strong. The reviewer would prefer to see additional technical voices at the table.

Reviewer 3:

The reviewer acknowledged that the combination of PNNL characterization and formulation capabilities and PACCAR vehicle powertrain development works well for this project. However, the reviewer suggested that this project would also benefit from a catalyst washcoater to provide additional insight in how to optimize including washcoat components for proper function.

Reviewer 4:

The reviewer observed that the project is a CRADA between the key partners, PNNL and PACCAR. Nevertheless, it feels like the two partners are operating in parallel and only periodically exchanging information instead of operating as a combined team.

Reviewer 5:

The reviewer reported that PNNL had good collaboration with PACCAR, but questioned whether suppliers were involved. In one slide, it says that PACCAR is doing the coating of the substrates, but that seems unlikely. The reviewer requested knowing who else the team is working with on this.

Reviewer 6:

The reviewer indicated that it is not clear from the presentation slides what the specific nature and extent of collaboration are between PNNL and PACCAR.

Reviewer 7:

The reviewer said that PNNL and PACCAR are the only members of the team. It was not clear to the reviewer why such a challenging problem and external know-how has not been integrated into the team. The reviewer suggested that the presence of a catalyst supplier strong in SCR-DPF R&D and familiar with commercial benchmarks would have been very helpful. In the opinion of this reviewer, Umicore could be a good partner for this due to its R&D capability in this area (though the intention is not to promote one supplier versus another). The presentation also stated that PACCAR does the coating (Slide 14). The reviewer considered this strange to hear because PACCAR is not a coater. The reviewer questioned if it meant that “coated parts are supplied through PACCAR.” The reviewer highlighted that further clarification is needed. This is a complex problem; there is very little room for ambiguity or for playing with concepts. Clarity in strategy is of utmost importance.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer observed that the project has a reasonable future work plan based on the accomplishments so far.

Reviewer 2:

The reviewer offered that the proposed research is a logical extension of the work to date, but it does not seem compelling. Be prepared to answer why it should get funded and not others that may have more immediate relevance. The reviewer also asked how the results of this work will be publicized.

Reviewer 3:

The reviewer observed that it is stated (Slide 17) that future work is to focus on increasing NO oxidation (to NO_2). While increased NO_2 formation could assist soot removal, increased NO_2 by itself is a necessary condition for soot removal, but not sufficient, as also temperature and NH_3 play key roles, amongst other factors. The reviewer suggested to the investigators list "future work" via considering, first, what they want the end targets to be. Once those targets are clear, the next step is to set interim milestones (fitting the project timeline) to reach end targets. Looking at this presentation, it appears that time may not be a driver, which could take this exploration into a convoluted pathway with no clear time-based execution.

Reviewer 4:
The reviewer noted that the team should have a better plan to improve the functionality of the washcoat components. More understanding of the reaction mechanisms is required to appropriately alter the components. Using manganese (Mn) and other species that have been studied before at PNNL have limitations that are not appropriate for exhaust conditions. Also, the reviewer concluded that faster feedback from PACCAR would benefit direction at PNNL.

Reviewer 5:
The reviewer highlighted the need to address interaction between the standard SCR reaction and soot consumption with NO_2 in the future work. In addition, low-temperature behavior is equally important as durability, which should be addressed as well.

Reviewer 6:
The reviewer noted that it seems like progress is very slow and struggles to be relevant to real-world needs for PACCAR.

Reviewer 7:
The reviewer asserted that the future work is still following up all the sidetracks, and that there is no focused pathway to a product.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that this project directly addresses issues of durability for heavy HD diesel engines. It indirectly addresses issues of cost-effective emissions control, especially for heavy HD diesel engines.

Reviewer 2:
The reviewer noted that all the information generated in this project probably has use in some part of aftertreatment.

Reviewer 3:
The reviewer commented that this work appears to be relevant to the development of aftertreatment systems that fit the packaging and temperature requirements of OEMs. This effort is supported in the OEM community.

Reviewer 4:
The reviewer said that, yes, it generally supports DOE objectives.

Reviewer 5:
The reviewer suggested that SCR-on-DPF may be one of the trends moving forward, which can reduce overall packaging volume and potentially improve performance and durability, thus overall system cost.

Reviewer 6:
The reviewer observed that any increase in soot oxidation in emission control systems (in this case in a combined SCR-DPF) would help reduce system backpressure, in turn increasing fuel economy, meeting DOE's strategic goal. Apart from this long-term goal, and showing some benefits of metal oxides (ZrO_2) in a DPF-SCR in the interim, in the opinion of this reviewer this project will have a hard time meeting, by 2020, its ultimate goal of yielding an optimized SCR-DPF beyond existing industry benchmarks.

Reviewer 7:

The reviewer indicated that integration of NO_x conversion over SCR catalyst and passive soot oxidation over DPF into one device for HD applications would be beneficial from cost, packaging, and thermal management perspectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked that resources appear to be sufficient. No change in resources is recommended.

Reviewer 2:

The reviewer stated that it looks like the budget received from DOE to date is less than what would have been expected based on the total budget. Nevertheless, to date it looks to the reviewer like the project team has been able to meet their project milestones with the available budget.

Reviewer 3:

The reviewer noted that the current resources seem sufficient in light of the project scope and schedule/milestones.

Reviewer 4:

The reviewer commented that, while good work takes time, there is immediate need for enhanced soot-oxidation in a SCR-DPF. This team should seriously consider integrating external expertise of a coater for several reasons. First, to refine its approach (does not mean sacrificing its novelty). Another reason is to make sure the intermediate steps are not only tangible but fit in a reasonable timeframe for the stakeholders. Lastly, it could integrate industry's notable expertise in this investigation, accelerating its undertaking.

Reviewer 5:

The reviewer observed that the team should have enough funding to complete the research, because only 41.7% is consumed.

Reviewer 6:

The reviewer indicated that based on the progress, the resources seem excessive.

Reviewer 7:

The reviewer offered that too many side trip investigations cost money.

Presentation Number: acs120
Presentation Title: Enabling Lean and Stoichiometric Gasoline Direct-Injection Engines through Mitigation of Nanoparticle Emissions
Principal Investigator: Will Northrup (University of Minnesota)

Presenter

Will Northrup, University of Minnesota

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

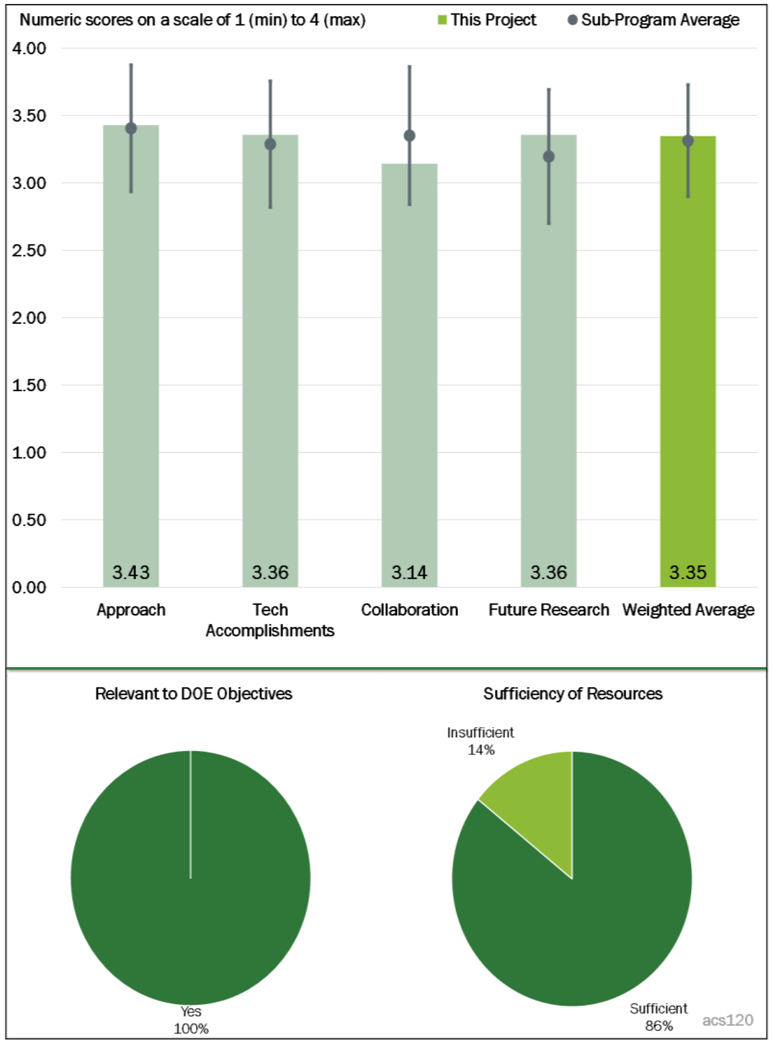

Figure 1-30 - Presentation Number: acs120 Presentation Title: Enabling Lean and Stoichiometric Gasoline Direct-Injection Engines through Mitigation of Nanoparticle Emissions Principal Investigator: Will Northrup (University of Minnesota)

Reviewer 1:

The reviewer stated that this activity addresses an important area within the emissions control milieu—the generation and control of PM during lean combustion. In the reviewer's opinion, the general mechanisms of PM formation and control require significant fundamental investigation, and the reviewer found the team's use of the in-cylinder luminosity technique to be intriguing and exciting. The reviewer commented that the ability to use this tool to diagnose diffusion flames as a direct source of enhanced PM formation was excellent.

Reviewer 2:

The reviewer observed solid plans to complete the investigation of the effects of different fuels on the PM/particle number (PN) emissions from the vehicle and then to investigate the effect of aftertreatment with those same fuels.

Reviewer 3:

The reviewer commented that PM emissions from gasoline engines are indeed not understood and adequate methods are yet to be developed. This project targets overcoming these barriers.

Reviewer 4:

In the reviewer's view, the approach seems a reasonable mix of focus on the fundamentals of fuel, in-cylinder particle analysis, as well as fuel chemistry. Also, there is a mix of models borrowed from the literature integrated into the analysis of test data.

Reviewer 5:

The reviewer noted that PM emission control is of considerable importance for aftertreatment system development of the next-generation gasoline vehicles. Fuels may have a profound impact on the actual PM emission control efficiency, and a systematic fundamental study is largely absent in the area. The reviewer stated that the project picks the right perspective to tackle the problem in the face of future needs for accurate measurement mass and number in real-time engine dynamometer operations.

Reviewer 6:

The reviewer remarked that the approach over several years appears well thought out and sequenced while finding it unusual to see a project at the AMR for the first time in its third year. Maybe, the reviewer opined, there were timing issues in the project that were not covered in the slides, but the second year is an important time to be receiving suggestions because there is time to respond.

Reviewer 7:

The reviewer suggested an increased emphasis on transient testing, including some several operating regions from certification test cycles. The reviewer was of the opinion that it might be useful to add an intermediate ethanol—say 30%—to understand at what level the increase in particulates is first seen. The reviewer asserted that injection technology needs updating by going up to 300 bar.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer pointed out that the team has made excellent progress on technical elements for a difficult project. The test stand is generating very useful and complex data.

Reviewer 2:

The reviewer had several positive comments: Using in-cylinder luminosity gave unique insight. The direct collaboration with fuel manufacturers to correlate fuel characteristics to combustion and PM was encouraging. The team was also able to demonstrate the link between combustion mode and generation of PM and, more specifically, highlight the case where the correlation breaks down (lean homogeneous). The reviewer appreciated the team's attempts to provide a means of linking particle density and diameter for real-time PN to mass.

Reviewer 3:

The reviewer stated that it was nice to see a systematic evaluation of stoichiometric, homogeneous lean, and stratified lean operation on the PM/PN emissions and then the correlation between the PM and the PN for the three operating modes. It was interesting to the reviewer that the high ethanol fuel produced the highest PM/PN under lean homogeneous mode, but the lowest PM/PN under lean stratified mode and the next-to-lowest PM/PN under stoichiometric operation.

Reviewer 4:

The reviewer noted that the following are all important: the fundamental understanding of the impact of ethanol—the particulate matter index (PMI) does not apply to lean burn—and the finding of high sub-23 nanometer (nm) particles for lean GDI. The reviewer commented that it is important that a physical/chemical justification be provided that explains the above.

Reviewer 5:

The project appears to be on track overall to the reviewer; however, it does appear that milestone 3.3 is a little behind schedule. The principal investigator (PI) does appear to have a holistic explanation for the PM/PN formation across fuel chemistry and combustion.

Reviewer 6:
The reviewer found the results thus far to be very interesting. The source of the unexpected sub-23 nm particles needs to be confirmed. It appears that a choice on a GPF and TWC was made, but not discussed. Those studies in Task 4 are incomplete, but the reviewer suggested that a view of how the team is going, especially in the third year, beyond the figure in the top of Slide 10 would have been very useful. The reviewer assumed that this has all been done well. It appeared to the reviewer that the analysis tools are very relevant and are giving good data.

Reviewer 7:
The reviewer observed that the proposed project involves abundant test cell work that requires substantial hardware and labor input, and unexpected delays are not uncommon is such context. However, the reviewer noted that the key findings so far are more qualitative than quantitative, mainly due to the test cell engine control issues as the PI claimed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that evidence was presented of good collaboration with FCA, BP, ORNL, and AVL.

Reviewer 2:
The reviewer found the team to have a good range of collaborators drawn from both industry and academia. The reviewer noted that the teams' wishes to expand the range of partnerships as the project progresses, but is the reviewer appreciated that this is still the early days in the activity.

Reviewer 3:
The reviewer stated that collaboration among the university, industry partners, and ORNL appears to be well coordinated. Given the significance of particle treatment inside a coated GPF, the reviewer said that adding catalyst expertise to the team appears warranted.

Reviewer 4:
The reviewer asserted that collaborators appear potentially sufficient to a broadly based project such as this. The reviewer suggested that it would be good to have more detail on what parts of FCA, BP, and ORNL are involved along with the names of those resources thus far into the project, as this helps provide understanding of the directions being covered. The reviewer asked if there are meetings by phone or in person by collaborating organizations and what their frequency is.

Reviewer 5:
The reviewer commented that the involvement of FCA and BP could be deeper on the engine and fuels aspects. The reviewer noted that AVL provides expertise for the test stand diagnostic. The reviewer asserted that the contribution of ORNL was not clearly articulated.

Reviewer 6:
The reviewer stated that there is much work done in other groups on understanding particulates from lean GDI and impact of GPFs. The reviewer suggested that it will be good to collaborate with those projects and also differentiate the work being done here.

Reviewer 7:
The reviewer acknowledged that the project seems to have the right partners and collaborators to work together. However, as previously mentioned, the reviewer stated that the project is a laborious work that must require high expertise in hardware and controls. The resources seem to be limited in the opinion of the reviewer.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that there is a logical plan going forward.

Reviewer 2:
The reviewer commented that the project is still in its early stages but found it encouraging to see that the team has a vision for future activities that are closely aligned with the needs of their partners and the scope of the DOE mission. The reviewer noted that the team is also showing a willingness to expand the activities, again hopefully with a perspective of aligning with a wider range of industry partners to maximize the value and impact of these activities.

Reviewer 3:
The reviewer indicated that the project appears to be well organized and planned. The PI has a clear list of targets and deliverables in the future work list. The reviewer stated that the task “Fuel-dependent soot oxidative reactivity” markedly calls for the need to have a particle-experienced catalyst chemist on board the project.

Reviewer 4:
The reviewer suggested that the investigation into the effects of aftertreatment with the different fuels will be interesting. The reviewer asked if there are plans to investigate different GPFs with different characteristics or whether the planned work is confined to a single GPF.

Reviewer 5:
The reviewer found the future work to be well-planned out. The reviewer recommended that the team investigate multiple GPF+TWC configurations in order to generate more reliable and comprehensive conclusions.

Reviewer 6:
The reviewer stated that the items in Tasks 3-6 that are going to be covered will be very important to understand the part that particulates are playing in aftertreatment issues for GDI engines. The reviewer pointed out that stoichiometric engines are covered in the title of the project and results are needed there, if only as a reference. The reviewer assumed that those are included, if not explicitly.

Reviewer 7:
The reviewer proposed that it will be very useful to add a definite objective that aims to explain fundamentally why there is an increase in sub-23 nm particles, why the PMI does not apply to lean GDI (and whether there is another relationship that holds), and why PN increases at high ethanol. Also, the reviewer would like to see an increase in the transient experiments.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that this is a highly relevant project in support of DOE objectives.

Reviewer 2:
The reviewer responded affirmatively and commented that the goals of this project are well-aligned with the United States Driving Research and innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) ACEC Roadmap.

Reviewer 3:

The reviewer noted that lean GDI offers improvement in fuel economy, but particulates need to be understood. Also, the reviewer said that the study of higher ethanol content fuels is in line with the direction for increased use of renewable fuels.

Reviewer 4:

The reviewer asserted that PM/PN aftertreatment will be necessary for GDI vehicles to satisfy the most stringent PM/PN standards.

Reviewer 5:

The reviewer found the approach to the R&D to be technically sound and noted that the team is employing state-of-the-art techniques to probe deeply into the mechanisms of PM generation. As such, the reviewer commented that the team is already realizing significant technical progress towards fulfilling project goals as well as providing a high level of value to their industrial partners. The scope of the partnership is good but should be expanded given the relevance, value of the data, and insight generated. The reviewer emphatically judged the potential value of this project to be at the highest level and expected to see further interesting developments in 2019.

Reviewer 6:

The reviewer observed that the understanding of what is needed to deal with particulates and meeting emission standards are key to developing strategies for using GDI engines to meet fuel economy and emission standard guidelines.

Reviewer 7:

The reviewer remarked that particulate matter emission control is of considerable importance for the aftertreatment system development of the next-generation gasoline vehicles. New knowledge is anticipated in the area of fuel impacts, GPF+TWC configuration impacts, and measurement strategies. The reviewer stated that the project fits the scope.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked that there are excellent facilities.

Reviewer 2:

The reviewer observed that the resources for this project appear to be sufficient.

Reviewer 3:

The reviewer stated that resources seem sufficient given the progress made year to date and the future work planned.

Reviewer 4:

The reviewer noted that the resources appear to be sufficient for this project.

Reviewer 5:

The reviewer said that there seems to be a good balance between resource and delivery. Obviously, if the scope of activities is expanded, the funding should reflect this.

Reviewer 6:

The reviewer asserted that the experimental resources appear to be well provided at the University of Minnesota. The reviewer commented that further resources may be coming from collaborators, but are not spelled out in this presentation.

Reviewer 7:

The reviewer noted that the project seems to have the right partners and collaborators to work together. However, as mentioned previously, the project is a laborious work that must require high expertise in hardware and controls. The reviewer commented that the resources seem to be limited according to the non-conclusive progress and preliminary interpretation of the data.

Presentation Number: acs121
Presentation Title: A High Specific Output Gasoline Low-Temperature Combustion Engine
Principal Investigator: Hanho Yun (General Motors)

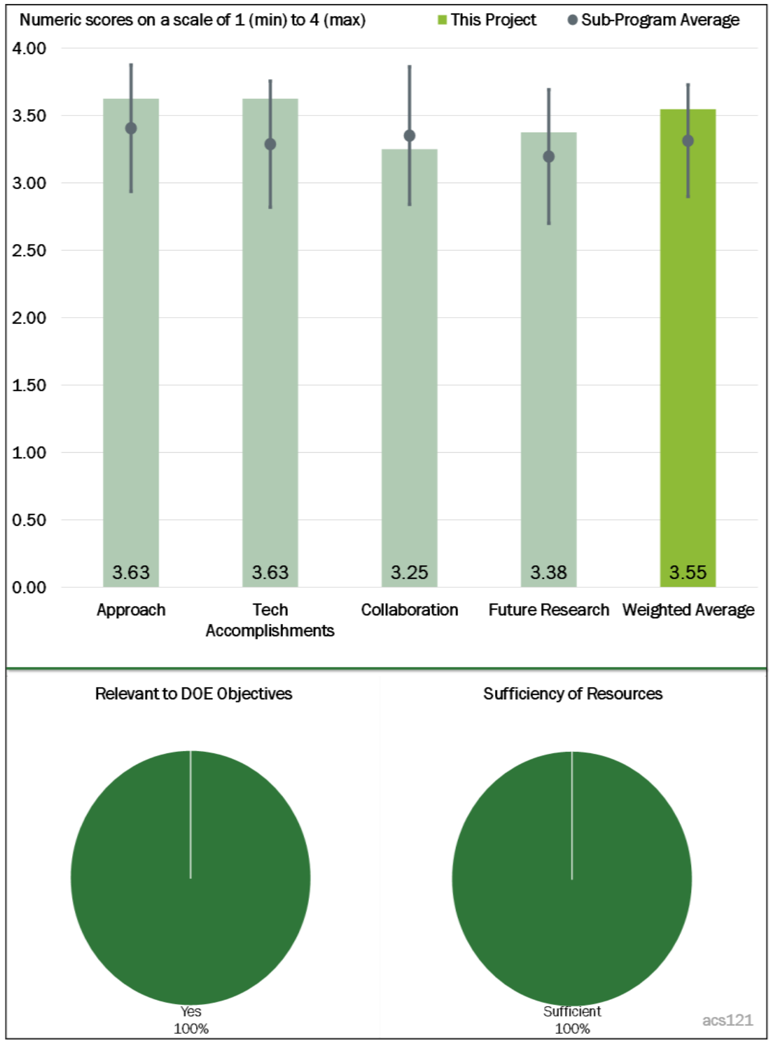

Figure 1-31 - Presentation Number: acs121 Presentation Title: A High Specific Output Gasoline Low-Temperature Combustion Engine Principal Investigator: Hanho Yun (General Motors)

Presenter
Hanho Yun, General Motors

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer pronounced the project to be a very strong and well thought out approach to addressing the technical barriers of significant improvements in fuel economy through the introduction of LTC in combination with boosted SI operation. The reviewer noted that the approach integrates all key areas—downsizing and boosting, low-cost emissions controls, lean LTC, LTC ignition control, and physics-based control. The reviewer stated that the approach appears very ambitious for the funding level, but great progress has been made. While all of the key areas show great innovation in the approach, the reviewer found the low-temperature ignition system to be especially interesting. The team has developed a very unique and controllable ignition system without excessive complexity. The reviewer said that this appears to be an important enabler for ensuring robust operation across the multiple combustion strategies being used to cover the entire speed-load operating range.

Reviewer 2:
The reviewer observed that this project is a good combination of advanced injector, ignition system, air handling, aftertreatment, and combustion strategies to achieve the overall goal of improving fuel economy, engine robustness, and lower noise.

Reviewer 3:
The reviewer stated that the approach for LTC on this project looks well designed and thought out with the higher energy ignitions system able to address the unstable points of operation, thus contributing to a smoother transition between modes of operation.

Reviewer 4:

The reviewer thought that the approach was well done as the presenter explained the four strategies as a function of load. The key will be in the mode switching as load changes.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that identifying the four modes of operation is a key accomplishment. The next step is mode switching in the view of the reviewer.

Reviewer 2:

The reviewer referenced prior comments. The reviewer stated that the technical accomplishments appear on target with excellent results. This includes a demonstration of 16% improvement in net fuel consumption with very low indicated NO_x for a 2,000 revolutions per minute (rpm), 2 bar net mean effective pressure condition. The reviewer pointed out that comparing HRRs for LTC versus conventional operation was very helpful in understanding the accomplishments and future opportunity. The reviewer commented that there was also a great example of how the ignition system "stabilizes" the combustion process to avoid "problematic" cycles, a great accomplishment. The reviewer noted that the final discussion on lean LTC and the use of ignition, multiple injection, EGR, and valving to extend load range was very helpful.

Reviewer 3:

The reviewer noted that good progress was made in demonstrating the feasibility of the technology and its advantages. It will be good to compare the brake specific fuel consumption of this technology with other, similar high-efficiency ICEs.

Reviewer 4:

The reviewer found the technical accomplishments to be detailed nicely and thoroughly. The reviewer said that this was very nice work completed with a lot of information on the slides that was not covered in the presentation. This reviewer would have liked more discussion on the valving strategy on Slide 11, but this was not extensively covered in the presentation so it was not clear what this chart is showing and how this was done.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the GM team has an impressive group of suppliers to bring together diverse expertise from across the industry. The reviewer was not sure the suppliers would technically be collaborators, but they are supporting the project to meet the objectives of the original proposal. The reviewer called this a great team.

Reviewer 2:

The reviewer stated that there was good collaboration with Tier 1 suppliers.

Reviewer 3:

According to the reviewer, there seemed to be a clear collaboration between GM and Delphi. The reviewer assumed that there was communication with the other four partners. The reviewer suggested that it would be good to highlight that in the next review.

Reviewer 4:

The reviewer noted that the partners/suppliers are well qualified and have significant expertise to offer to the project. However, by only using suppliers as partners, the team is excluding universities and national laboratories, which could strengthen the team and the project. The reviewer proposed that the team should consider adding these organizations to enhance the diagnostics or modeling aspects.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the proposed future work was appropriately cited as mode switching.

Reviewer 2:
The reviewer commented that the proposed future research appears on target on what needed to be done to move this concept forward. The team is very aware of the barriers and challenges to developing a technology for market.

Reviewer 3:
The reviewer remarked that the project was mostly well planned, but there were no details on mitigating the risk if the aftertreatment system is not sufficient to meet the future NO_x target. Also, the reviewer asked about PN emissions.

Reviewer 4:
The reviewer said that the future work identifies items like developing a “seamless” mode-switching strategy and “robust” hot and cold operation. The reviewer asked what the definition of these terms was. The reviewer stated that it would be better to identify specific, measurable goals.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that LTC is a key strategy for meeting future emissions and fuel economy. The reviewer recommended that DOE continue this research.

Reviewer 2:
The reviewer pointed out that this project clearly supports the overall DOE objectives by developing a technology and strategy for significant improvements in fuel economy while addressing critical barriers and challenges for market introduction.

Reviewer 3:
The reviewer said that this project addresses multiple objectives relevant to DOE: namely, improvement to fuel economy, advancing LTC regimes for gasoline engines, engine controls for LTC, and emissions control challenges for advanced engine concepts.

Reviewer 4:
The reviewer agreed that this project demonstrates advanced ICE technologies, which support the DOE objectives of reducing fuel consumption.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer found the resources to be sufficient to achieve the stated milestone.

Reviewer 2:
The reviewer said that the resources for this project look appropriate.

Reviewer 3:
The reviewer indicated that resources seem appropriate.

Reviewer 4:

The reviewer stated that the team appears to be delivering a significant amount for the allocated resources. However, there were not comments on the resources being insufficient and the team appears on track to meet all deliverables.

Presentation Number: acs122
Presentation Title: Solenoid Actuated Cylinder Deactivation Valvetrain for Dynamic Skip Fire
Principal Investigator: Hermes Fernandez (Delphi Automotive Systems, LLC)

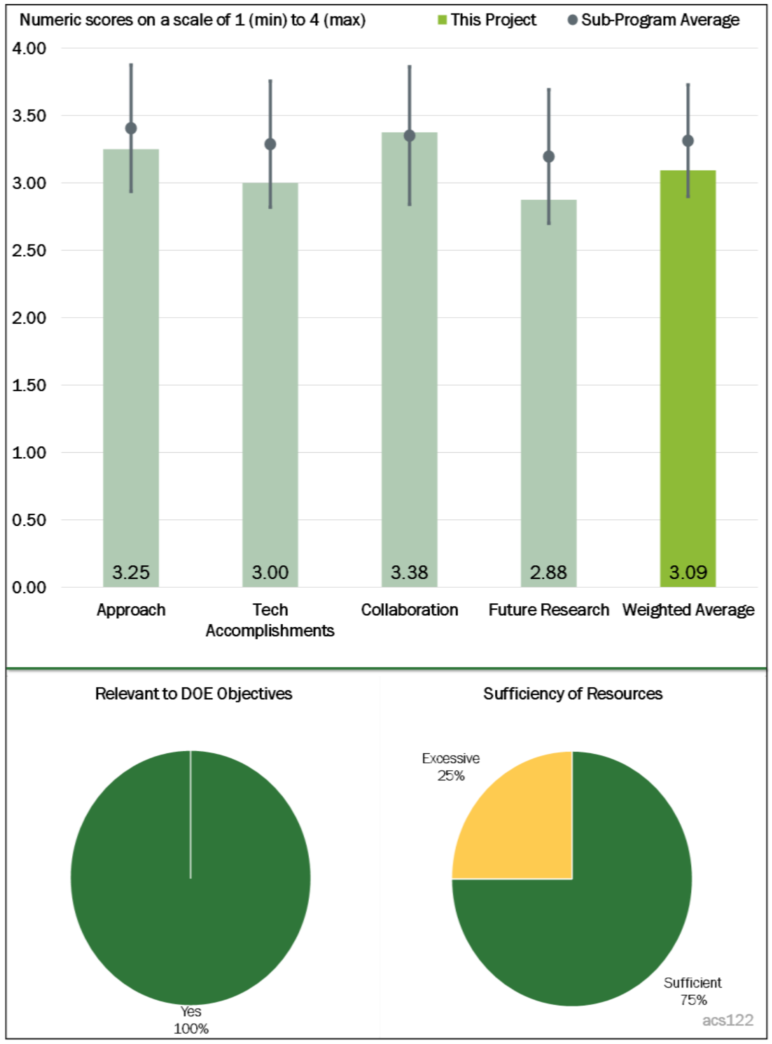

Figure 1-32 - Presentation Number: acs122 Presentation Title: Solenoid Actuated Cylinder Deactivation Valvetrain for Dynamic Skip Fire Principal Investigator: Hermes Fernandez (Delphi Automotive Systems, LLC)

Presenter
Hermes Fernandez, Delphi Automotive Systems, LLC

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer stated that the approach is very good. The reviewer said that the focus on the minimizing OEM engine integration modifications is great. This will be very important to OEM willingness to integrate across multiple platforms. The reviewer remarked that the approach is very well thought-out from engine control module to active control mount to solenoid actuation. The selection of electrified actuation over hydraulic also makes sense to the reviewer, especially with increased electrification infrastructure on current and next-generation vehicles.

Reviewer 2:
The reviewer commented that the approach of using a novel CD strategy to achieve 8%-10% fuel economy improvements is well-designed. The reviewer reported that the team is using engine simulation along with design to accelerate the concept and that a high-level overview of the process was given. The reviewer suggested that more details of the integrated system approach could have been provided. The reviewer stated that the figure on Slide 5 helped convey the concept, but comparing this approach to downsizing or conventional CD was not provided. The reviewer said that there were not many details on the underlying pathways of improvement (other than reduce pumping losses and “improve combustion thermodynamics”).

Reviewer 3:
The reviewer opined that the team is applying the Skip Fire technology to SAE type 2 valve train architecture to facilitate the market penetration of the technology. The team is using electric actuators to simplify integration on-engine, especially compared to hydraulic actuators. It was not clear to the reviewer that the

project really addresses purely pre-competitive issues though, given that the system is about ready for production release.

Reviewer 4:

The reviewer noted that the approach is sound for the rocker arm. The baseline fuel economy is for a modern engine that does not have CD. The reviewer recommended that the team compare DSF versus the authors' intended baseline without CD and then compare those results to modern engines with fixed CD (i.e., not DSF).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the technical accomplishments are strong and consistent with the plan. The reviewer noted that the team developed and reviewed 22 concepts before reducing to 6 for further study. The reviewer had a question about the durability of the lock pin, which was addressed somewhat during the question and answer (Q&A) session with another reviewer. The team is evaluating durability with standard methods. The reviewer noted that progress on milestones is also very good.

Reviewer 2:

The reviewer stated that work seems to be progressing well on the rocker arm development, and testing will occur later.

Reviewer 3:

The reviewer found the accomplishments to date to be appropriate, but seemed thin compared to what is in store for FY 2018. The final design concept is complete, including on-engine packaging analysis for the initial demonstration application. The reviewer pointed out that the team has tried to take a manufacturer-neutral approach to designing the system. The reviewer noted, as an aside, that the target fuel economy improvement is over the drive cycle and compared to a modern engine without CD.

Reviewer 4:

The reviewer stated that this is the first year of the project. According to the reviewer, the accomplishments focus on the high-level aspects of the engine simulation, the use of solenoid actuation, and design analysis. The importance of the actuator driver module development was presented. The reviewer remarked that more technical details of what the underlying improvements pathways could be presented. The reviewer stated that the presenter did not have information regarding what happens to exhaust temperature during different firing densities and was very much focused on design elements.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the Delphi team is partnered with Tula Technology and appears to have a great partnership and strong coordination. Combining a strong supplier like Delphi and the developers of the DSF technology make for a strong team.

Reviewer 2:

The reviewer noted that the team is Delphi Technologies and Tula Technology. It looks like the team has made a reasonable split of the work between the two based on their strengths and interests.

Reviewer 3:

The reviewer found the partnership between Delphi and Tula to be well coordinated and a great match for achieving the technical goals of the project. It was not clear to the reviewer if the project will be considering aftertreatment challenges as presented.

Reviewer 4:

There is clear collaboration between Delphi and TULA, according to the reviewer, who recommended comparing DSF to fixed CD for a better understanding of the benefits of DSF.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that the proposed future research makes sense in meeting the objectives of the program. The overall project approach, which also directs the future research, is excellent.

Reviewer 2:

The reviewer remarked that the proposed future research looks to follow a well-developed product development cycle plan. The remaining challenges and barriers to actually achieving the targets are not well laid-out in terms of linking to the proposed future research.

Reviewer 3:

The reviewer rated the project as good and stated that the rating would have been higher if there was comparison to fixed CD to better understand DSF benefits.

Reviewer 4:

The reviewer opined that the plan for FY 2018 seems ambitious, even though one of the milestones is nearly met. The reviewer pointed out that the team plans to build and test the demonstrator engine, with particular emphasis on its fuel economy. Nevertheless, if General Motors is introducing DSF on a couple of production engines starting in 2019, the reviewer questioned why the Department of Energy needs to subsidize the development of the technology. For example, the reviewer noted, several of the proposed FY 2019 activities look to support production, such as durability or design validation testing, which are not development activities. Demonstrating the fuel economy benefits is absolutely critical for this project.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer commented that the dynamic skip fire approach is very relevant to meeting the overall DOE objectives by enabling engine operation at conditions of maximum BTE for a wider range of speed/load points. For a further strengthening of the relevance, the reviewer mentioned that Delphi is addressing potential barriers and challenges to widespread market implementation. More specifically, according to the reviewer, Delphi is developing a system that an OEM will be able to integrate with minimal modifications, and they are ensuring durability of the device.

Reviewer 2:

The reviewer stated yes; various forms of CD are being used to improve aftertreatment systems and fuel economy. This reviewer further advised that it will be good to understand the benefits of DSF.

Reviewer 3:

The reviewer noted that the purpose of the dynamic skip-fire technology is to improve engine efficiency, especially in boosted direct-injection spark-ignition engines.

Reviewer 4:

The reviewer stated that this project supports overall DOE goals of improving fuel economy, and addressing barriers to use advanced technologies. The reviewer opined that the objectives were only loosely tied to the U.S. DRIVE goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the use of electrically actuated dynamic CD is a difficult endeavor. The team appears to have the resources to accomplish the proposed goals.

Reviewer 2:

The reviewer commented that resources seem sufficient.

Reviewer 3:

The reviewer stated that resources appear to be sufficient. The reviewer observed that there were no comments/concerns from Delphi nor any issues in the presentation.

Reviewer 4:

The reviewer found the overall budget to be appropriate for the scope of work. Nevertheless, if DSF is being introduced into production vehicles, the reviewer questioned why the Department of Energy needs to subsidize 50% of this technology demonstration project.

Presentation Number: acs123
Presentation Title: Temperature-Following Thermal Barrier Coatings for High-Efficiency Engines
Principal Investigator: Tobias Schaedler (HRL Laboratories)

Presenter

Peter Andruskiewicz, General Motors

Reviewer Sample Size

A total of six reviewers evaluated this project.

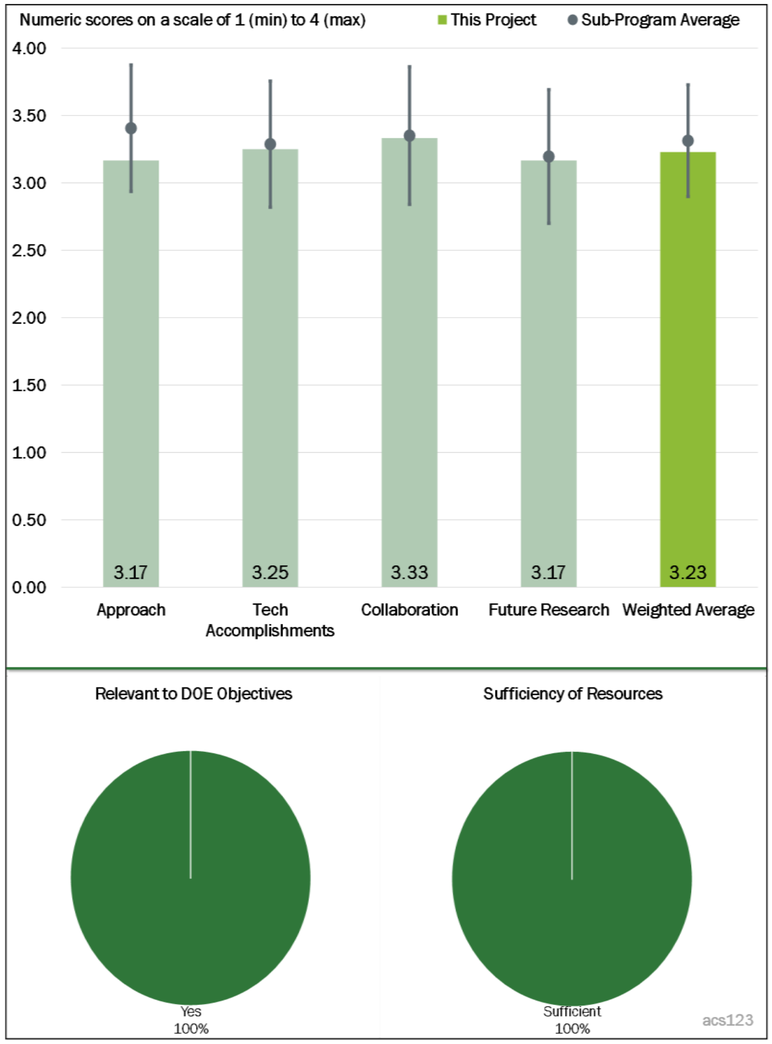

Figure 1-33 - Presentation Number: acs123 Presentation Title: Temperature-Following Thermal Barrier Coatings for High-Efficiency Engines Principal Investigator: Tobias Schaedler (HRL Laboratories)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer opined that a "Temperature Following Thermal Barrier Coating" would certainly be superior to simple ceramic thermal barriers. The reviewer stated that the modeling appears to be solid and shows real potential for benefits. The approach to address the significant challenges of applying sintered nickel micro-shell spheres is very reasonable. The reviewer noted that this is a high-risk, challenging enabling technology with potential for significant payoff if successful. The reviewer said that this is an appropriate use of DOE resources for low TRL research.

Reviewer 2:

The reviewer liked this project very much. The reviewer remarked that the project is pursuing the most beneficial way to reduce heat transfer from the cylinder while maximizing the benefit in terms of reduced fuel consumption and overall thermal management within the engine. The reviewer opined that the team's fundamental approach demonstrates a very high level of technical understanding of what needs to be done.

Reviewer 3:

The reviewer commented that there was a good approach to make a breakthrough in thermal barrier coating performance for controlling heat rejection. The team did a good job presenting needs across the entire cycle. The reviewer stated that there was a good comparison of conventional TBC during combustion and expansion. The approach to overcoming the stated barriers is promising.

Reviewer 4:

The reviewer noted that this approach is highly relevant to managing heat losses, one of the more elusive barriers to achieving engine efficiency close to theoretical and pragmatics limits. The modeling appears to have captured the subtle effects of fuel trapping as well as thermal swings. The reviewer stated that the difficulties of sealing layers were experienced in prior work many years ago and pointed out that more references to previous approaches and experience would have made the presentation a little stronger. With the world-leading capabilities in materials and coatings, development and characterization at the DOE laboratories, the reviewer found it surprising that there are no laboratory partners in the project.

Reviewer 5:

The reviewer remarked that this is a high-risk project. Thermal barrier coatings have been pursued many times in the past and have had shortcomings, both with durability and with effectiveness. The reviewer asserted that the temperature-following coating with low heat capacity and low conductivity will solve many of the effectiveness problems, but the durability issues appear to be persistent. Using this material in the exhaust ports with the steel casting inserts appears to make sense, in the reviewer's opinion, as the nickel foil coating does not seem critical here. However, for the in-cylinder components (piston and valves), it appears to the reviewer that there needs to be further development on the coating and sealing processes. As a result, the reviewer suggested de-emphasizing the engine tests until the material coating and sealing can be improved to raise the confidence that engine tests will be more successful.

Reviewer 6:

The reviewer stated that this project concerns development of TBCs that will decrease heat loss from the combustion chamber of an engine as TBCs are a well-known technology for this purpose. The presentation noted that effective TBCs could increase fuel efficiency by 4%-8%, to which the reviewer suggested that the PI define what is meant by "fuel efficiency" as there are many possible definitions. The reviewer requested that a quantitative connection be established between a TBC metric and the 4%-8% target. When the PI notes that further improvements will enable 4%-8% efficiency gains and increase durability, the reviewer requested that the basis for this expectation be provided—the connection between a percentage gain and a TBC metric.

The PI notes the importance of thermal conductivity (k) as a metric of TBC, and this reviewer indicated that some data are reported in the presentation. Tasks are associated with measuring it as well that extend to 2019. The reviewer asked how k and porosity were measured as well as the accuracy of the measurements, and advised that error bars should be included in the measurements. The reviewer commented that the project as presented seemed not to state anything about thermal contact resistance (R_c), a critical parameter that will control TBC performance to an extent. The reviewer stated that some discussion of how R_c was measured, or will be measured, and how its effect was or will be incorporated in the modeling effort needs to be included in the project. Similarly, the reviewer remarked that adhesion measurements to assess bonding strength of the TBC seem also to be a critical parameter that will control performance. The importance of bonding was noted in the presentation though the metrology for measurement was not noted. The reviewer requested a discussion of how specifically a target efficiency value is quantitatively linked to any metric of a thermal barrier coating (k, R_c, thickness, bonding strength, etc.). The project seems to rely on such a link but the presentation was not quite clear on this point.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer indicated that the team has made good progress on a challenging, high-risk project.

Reviewer 2:

The reviewer noted that the project team has made good progress. The team has developed a thermal barrier with the desired thermal properties and demonstrated that the material can survive in the engine environment for short periods of time. The reviewer remarked that the challenges for the project team have been identified and courses of action have been identified to address them.

Reviewer 3:

The reviewer found that a lot of progress has been made with this technology, and clearly, the porous nickel shells are exciting for thermal barrier coating applications. The reviewer stated that many barriers remain on the bonding and sealing of the coating.

Reviewer 4:

The reviewer commented that the team has made significant progress on the development of the TBC insulation and did an excellent job showing current progress with coating issues. The reviewer found a good use of diagnostics to present finding on compaction. The modeling efforts tied to the project are well integrated and help explain observations. Despite this being the first year, the reviewer observed that the project has been reviewed and the team has made some notable accomplishments. The reviewer stated that more information about the experiments conducted and the amount of time and conditions the coated valves experienced could have been presented.

Reviewer 5:

The reviewer said that the project is highly focused on solving the problems of thermal properties and the necessary sealing layer. Modeling achievements are good progress and insightful. Nice innovations on materials brought praise from the reviewer. The project claims potential benefits in reducing engine knock, but the reviewer said that the explanation was not complete nor rigorous.

Reviewer 6:

Comments from the reviewer included statements about the reported progress on performance of TBCs. The importance of a surface sealing layer was noted. The project also tested pistons coated with TBCs where some success was noted. The reviewer stated that a failure mode appeared due to delamination or poor bonding of the coating to the piston. A solution was suggested based on improved brazing and adhesion. The reviewer mentioned a discussion of thermal modeling and the role of bonding. According to the reviewer, the presentation did not provide details regarding what was involved with the modeling effort.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer indicated that, while there is not a long list of collaborators, the parties involve are the right parties. HRL is leading the technology for the TBCs. GM is an engaged industrial partner that has the capability to bring the technology to market. Together, the reviewer opined that the team has the expertise to study and overcome barriers and move the technology forward.

Reviewer 2:

Being an industrial project, the reviewer commented that specific collaborators have been identified for their technical capabilities and they are actively engaged in the project.

Reviewer 3:

The reviewer pointed out that this project is a collaboration between HRL laboratories and GM, with GM being a subcontractor for engine testing. Other companies are being engaged.

Reviewer 4:

The complexity of this approach requires the right team, which seems to have been assembled. More information on the coordination across the teams could have been provided, but a very solid team. The reviewer remarked that the project milestone slide does show clear expectations of the primary team while collaboration with other partners is not yet clear.

Reviewer 5:

The role of GM is shown well enough in the schedule chart according to the reviewer, but other potential involvement by Federal Mogul, 3M, et al is not described. The reviewer posited that other partners with prior experience in this approach and exceptional materials characterization capabilities (not to slight HRL or GM) are missing.

Reviewer 6:

The reviewer stated that the team seems appropriate, but the potential is there to address some of the challenges by involving another collaborator.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that there was a very good summary of barriers to achieve goals and the future research is well-aligned to those goals. According to the reviewer, there was a very clear discussion of future research needed for both the sealing of the microsphere insulation and the bonding issues with the path for alternative piston material to facilitate bonding.

Reviewer 2:

The reviewer reiterated that the researchers have identified the principal challenges that need to be addressed and developed a future work plan to address them.

Reviewer 3:

The reviewer noted that the project team will be sourcing steel pistons to (temporarily) mitigate issues with bonding to aluminum. The reviewer said that this is a good idea that can permit demonstration of the benefits, if any. The reviewer suggested that the developers may consider modeling the benefits of changing the contents or the internal pressure of the spheres. During Q&A, the speaker mentioned examining higher pressure air to improve durability. The reviewer asked if there could be any heat exchange benefit to changing the gas or gas pressure (even considering pressure [P] below ambient).

Reviewer 4:

The reviewer said that the future work includes activities associated with fabrication of the TBCs, sealing, and examining different piston materials and coatings. However, the reviewer found no mention of thermal characterization of the TBCs, specifically regarding direct measurements of adhesion or bonding strength, R_c or thermal conductivity (some measurements were reported on the latter, though). The reviewer stressed that these measurements would seem essential to the project and should be a centerpiece of the PI's evaluation of the TBCs under investigation.

Reviewer 5:

The reviewer proposed that the impact of coatings on engine knock needs further investigation and explanation. Otherwise, the focus on resolving issues with the coating and seal layer are paramount and the focus of most future work.

Reviewer 6:

The reviewer noted that the majority of the future work focused on sealing and bonding, which is the correct path forward for this technology given that those are the main barriers to the technology. The reviewer believed there are other areas where future work is necessary, including understanding the impact that the added piston weight will have on friction (especially if steel pistons are required), developing a more detailed understanding of the impact of the barrier coating on high load performance (knock), understanding durability of knocking on TBC durability, and many more. These areas are all secondary to the proposed sealing and bonding activities in the proposed future work.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer responded yes, from a broad perspective.

Reviewer 2:
The reviewer noted that this project is well aligned with enabling DOE objectives.

Reviewer 3:
The reviewer remarked that this has been, and continues to be, an important area of engine development: enhanced in-cylinder thermal management.

Reviewer 4:
The reviewer stated that heat losses remain as an unresolved loss mechanism for internal combustion (IC) engines. Coatings are a possible, yet unperfected, approach.

Reviewer 5:
The reviewer commented that the development of this technology supports DOE's goal of enabling higher efficiency engines. TBCs are an enabling technology that can improve engine efficiency for a number of different combustion strategies under various conditions.

Reviewer 6:
The reviewer asserted that this is a high-risk, challenging enabling technology with potential for significant payoff if successful. This is an appropriate use of DOE resources for low TRL research.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the resources and team appear to be sufficient for achieving the stated milestones.

Reviewer 2:
The reviewer found the program funding to be sufficient.

Reviewer 3:
The reviewer remarked that the project resources appear to be sufficient to accomplish the project goals.

Reviewer 4:
The reviewer noted that significant taxpayer resources are obligated, but a 50% cost-share from the partners show strong commitment to develop this technology.

Reviewer 5:
The reviewer observed that for work at an exploratory, early- to mid-TRL level and overall objectives, the resources are very adequate. A 50% cost share seems high for this type of project.

Reviewer 6:
The reviewer stated that resources seem adequate although ultimate judgement would have to come from a cost/benefit analysis based on DOE's investment relative to the commercialization potential.

Presentation Number: acs124
Presentation Title: SuperTruck II—PACCAR
Principal Investigator: Carl Hergart (PACCAR)

Presenter

Carl Hergart, PACCAR

Reviewer Sample Size

A total of eight reviewers evaluated this project.

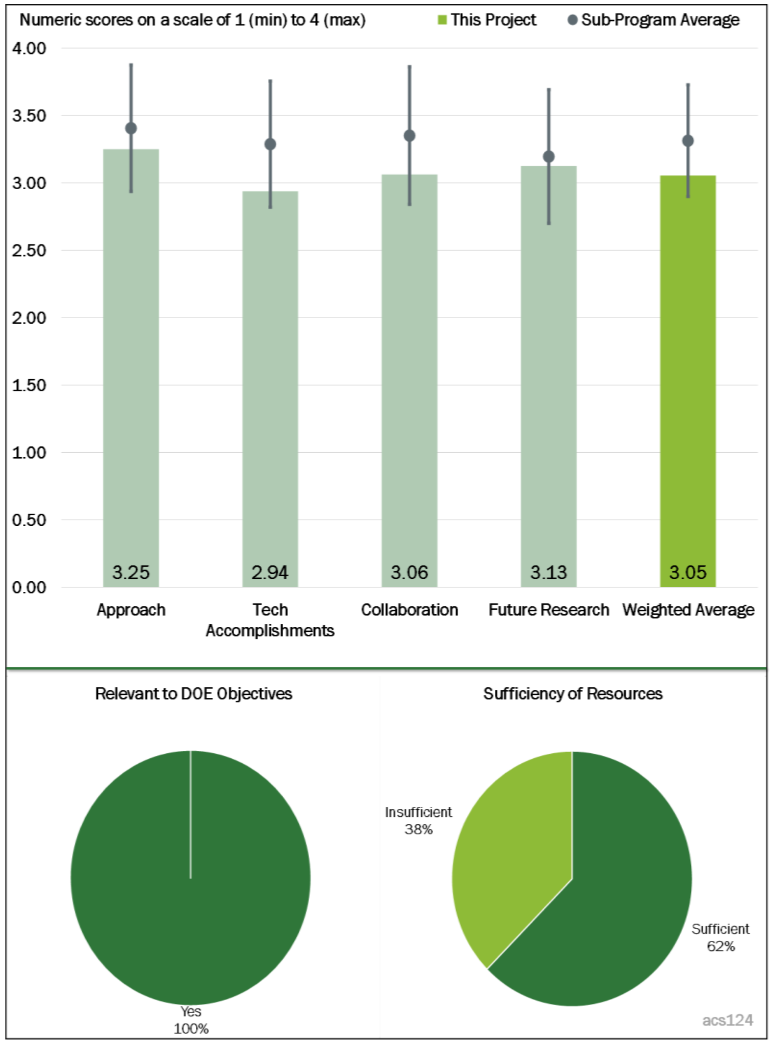

Figure 1-34 - Presentation Number: acs124 Presentation Title: SuperTruck II—PACCAR Principal Investigator: Carl Hergart (PACCAR)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found the emphasis on recognizing and meeting customer needs while achieving program goals to be outstanding and noted that the program includes all the necessary subsystems like cab, trailer, engine, etc.

Reviewer 2:

The reviewer stated that the project's overall approach was nicely laid out and includes multiple areas where gains will be needed to achieve the program targets.

Reviewer 3:

The reviewer remarked that the team is just getting started so it was somewhat difficult to evaluate.

Reviewer 4:

The reviewer commented that the project approach to achieving engine goals and vehicle freight efficiency goals appears well structured. The goals for the project are challenging, and as a mild criticism the technical approach does not have particularly innovative or high-risk elements. The hybrid powertrain assessment was well done.

Reviewer 5:

The reviewer noted that the project follows the other ST2 projects. This one appears to be lagging behind the others.

Reviewer 6:

The reviewer commented that the overall plans are good and fit well with what would be expected for a successful ST2 program. It is a little surprising that there was relatively little mention of route planning and other driver aid systems to increase efficiency. The reviewer remarked that there are also very few details on how the engine improvements are to be realized. The goals for that work are pretty lofty and experience from ST1 would suggest that they are not as easy to achieve as they look.

Reviewer 7:
The reviewer stated that the proposed approach includes many key elements of technologies. However, nothing is mentioned on tires and axles, both of which are critical to the success of this program.

Reviewer 8:
The reviewer observed that because the project is being initiated in 2018, the technology approaches have been selected. This project is clearly benefitting from the projects that came before. The evaluation and incorporation of the various technologies into the mule vehicle seems to be well thought-out. It was clear to the reviewer that PACCAR no longer has its choice of partners. It is especially clear in the areas of aerodynamics, WHR suppliers, and tire improvement. The reviewer was especially disturbed by the lack of plans and tire improvement, which has been shown to a major contributor to BTE.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that there was a balanced plan to look at all technical areas for opportunities.

Reviewer 2:
The reviewer asserted that the accomplishments have been primarily limited to pre-design analyses to converge on component types.

Reviewer 3:
The reviewer said that the achievements to date are pretty well aligned with the time since the project started. There are no measureable improvements to be evaluated yet so the assessment is entirely based on the plans and early analysis of the technical path.

Reviewer 4:
The reviewer noted that this program is early, only 5% complete. The results are appropriate for this level of completion. The reviewer expects to see much more results as time passes.

Reviewer 5:
The reviewer stated that this project started less than 1 year ago, and the AMR material was submitted after only 6 months so the technical accomplishments reflect the early stages of the program. The reviewer found it difficult to evaluate so early in the program.

Reviewer 6:
The reviewer said that this project is in its early stages, and accomplishments are mostly from simulation and design considerations, which is understandable. The analysis of various options for hybridization is insightful. The reviewer found the incomplete selection of a drive cycle and lack of WHR supplier to be negative factors.

Reviewer 7:
The reviewer observed that no devices were developed or tested.

Reviewer 8:
Although the program started 1 year late compared to its competitors, the reviewer remarked that lack of WHR experience could be a show-stopper moving forward because there would be no other alternative to achieving 55% BTE without the help of WHR. The reviewer opined that the issue becomes even more severe due to a lack of overall program experience on such a large scale for the program because PACCAR was not part of the SuperTruck I program.

The reviewer emphasized that it is not clear why “novel air management concepts” are claimed in Slide 12 where there is no indication or even a clue of why this is “novel.” A more detailed description would have been helpful to the reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Notwithstanding previous comments, the reviewer said that PACCAR has built a first-class team.

Reviewer 2:
According to the reviewer, PACCAR has done a nice job of assembling a total vehicle team including customer voices.

Reviewer 3:
The team looks good, but it was not clear to the reviewer how much collaboration and coordination across the team really exists from the work done so far.

Reviewer 4:
The reviewer commented that Slide 25 showed the major contributors nicely; however, on Slide 2, Mississippi State University was shown but was not mentioned in the presentation.

Reviewer 5:
The reviewer stated that project team had solid partners. Given some of concerns expressed during the presentation, the reviewer suggested that a ST2 customer focus group might help with the concern about “habitability challenges of drivers in aerodynamic trucks.”

Reviewer 6:
The reviewer noted that the roles of the various partners are defined, but except for Kenworth their achievements and involvement to date are not evident in the presentation.

Reviewer 7:
The reviewer remarked that there does not appear to be an emissions aftertreatment partner.

Reviewer 8:
The reviewer was surprised to see no partner on tires, which are one of the most critical elements of this program.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the plan seems to be excellent. A wide range of technologies will be evaluated, with a suitable plan for downselecting a vehicle system.

Reviewer 2:
The reviewer commented that the research plan was laid out nicely and easy to understand.

Reviewer 3:
According to the reviewer, a good plan is emerging for this new project.

Reviewer 4:
The reviewer stated that the plans look good, but there are a number of risks that do not appear to have good mitigation strategies because PACCAR is new to the SuperTruck (ST) program and does not have the ST1 work to start from; this is going to require them to improve the engine and truck efficiency much faster than the other teams, which may prove to be a big challenge.

Reviewer 5:
The reviewer noted that most of the project is yet to be carried out. The project team still needs suppliers in tires and WHR. The team seems to have full recognition of the necessary next steps. The reviewer commented that the future research items were not very detailed or specific. A higher degree of new approaches or innovation would be an improvement.

Reviewer 6:
The reviewer observed limited description and details.

Reviewer 7:
The reviewer believed that the scale-up to real devices will be much harder than implied by the plan and wished the team good luck.

Reviewer 8:
Because of the program starting late and also because of no prior experience with such a large-scale program, it would have been helpful to the reviewer to have the team provide more detailed information on the proposed future research, which can help the reviewer to understand how much the developer can move the program forward with high confidence. However, the reviewer opined that Slides 18 and 24 fail to demonstrate knowledge and understanding of the challenges of this program.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that the project is clearly aligned with DOE objectives.

Reviewer 2:
The reviewer noted that ST2 seems to be very relevant to the DOE objectives.

Reviewer 3:
The reviewer stated that the project should lead to improved transportation efficiency and reduced petroleum use.

Reviewer 4:
The reviewer commented that improved engine efficiency and overall freight efficiency are directly aligned with the DOE objectives.

Reviewer 5:
The reviewer said that Class 8 fuel/freight efficiency improvement is critical to our country.

Reviewer 6:
The reviewer observed that this project, like the other SuperTruck awards, pushes the performance of integrated truck systems to higher levels. Cost-effectiveness and commercialization are welcome criteria. The reviewer urged the team to make sure the drive cycle ultimately selected is highly relevant.

Reviewer 7:
If it can deliver, the reviewer said that the project would reduce fuel consumption, which supports the overall DOE objectives.

Reviewer 8:

The reviewer pointed out that all the HD manufacturers must have the same chance to upgrade their technology. So far, the reviewer believed that PACCAR is disastrously behind the curve.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that resources seem to be both necessary and sufficient for this large program.

Reviewer 2:

The reviewer found the resources to be aligned well with the amount of proposed work for this project.

Reviewer 3:

The reviewer stated that resources seem sufficient.

Reviewer 4:

The reviewer remarked that PACCAR and partners have capabilities to conduct R&D with the exception of emissions control technology.

Reviewer 5:

To catch up, the reviewer believed that PACCAR needs more resources.

Reviewer 6:

The reviewer expressed a little concern about basically achieving all of the ST1 and ST2 goals for only the ST2 budget, especially with systems like the WHR system that looks like it is going to need an outside partner not yet on the team.

Reviewer 7:

Whereas all of the SuperTruck projects appear adequately funded, individually, the reviewer questioned whether five teams (with the same goals) are really the most effective strategy to improve freight efficiency at the national scale.

Reviewer 8:

The reviewer commented that lack of experience makes the learning curve too steep. There may not be enough funding and time to allow the developer to use a trial-and-error approach to deliver the program goal. In addition, the reviewer stated that this program highly depends on WHR to achieve the program 55% BTE, but the developer has little or no experience on this matter, which makes this program highly risky.

Acronyms and Abbreviations

3-D	Three-dimensional
A/F	Air/fuel
ACEC	Advanced Combustion & Emissions Control
AEC	Advanced Engine Combustion
Al	Aluminum
Al_2O_3	Aluminum oxide (alumina)
AMFI	Additive-mixing fuel injection
AMR	Annual Merit Review
ANL	Argonne National Laboratory
ANN	Artificial neural network
ARDL	Akron Rubber Development Laboratory
AVL-18a	Fuel for engine testing
Ba	Barium
Br	Bromine
BTE	Brake thermal efficiency
C_3H_6	Propene
C70	Fullerene molecule used as a conductor
CA50	Crank angle position at which 50% of heat is released
CD	Cylinder deactivation
Ce	Cerium
CeO_2	Cerium oxide (ceria)
CFD	Computational fluid dynamics
CFP	Capillary flow porometry
CH_4	Methane
CHA	Chabazite
CHT	Conjugate heat transfer
CI	Compression ignition, conversion inflection

Cl	Chlorine
CLEERS	Cross-cut Lean Exhaust Emissions Reduction Simulations
CNG	Compressed natural gas
CO	Carbon monoxide
CPU	Central processing unit
CRADA	Cooperative Research and Development Agreement
CRF	Combustion Research Facility
Crr	Coefficient of rolling resistance
CT	Computerized tomography
Cu	Copper
DEER	Directions in Engine-Efficiency and Emissions Research
DEF	Diesel-exhaust fluid (urea)
DI	Direct-injection
DOE	U.S. Department of Energy
DPF	Diesel particulate filter
DSF	Dynamic Skip Fire
E10	10% ethanol content gasoline
E85	85% ethanol content gasoline
ECN	Engine Combustion Network
ECU	Engine control unit
EGR	Exhaust gas recirculation
EHN	Ethylhexyl nitrate
ELSA	Euler-Lagrange spray atomization
EMS	Energy management system
EPA	U.S. Environmental Protection Agency
EPR	Electron Paramagnetic Resonance
EXAFS	Extended X-ray absorption fine structure
FACE	Fuels for advanced combustion

FCA	Fiat Chrysler Automobiles
FTIR	Fourier transform infrared
FTP	Federal Test Procedure
FY	Fiscal Year
GCI	Gasoline compression ignition
GDI	Gasoline direct injection
GM	General Motors
GPF	Gasoline particulate filter
HC	Hydrocarbon
HCl	Hydrochloric acid
HD	Heavy-duty
HDD	Heavy-duty diesel
HPC	High-performance computing
HRR	Heat-release rate
HTA	Hydrothermal aging
IC	Internal combustion
ICE	Internal combustion engine
IR	Infrared
JMI	Johnson Matthey Inc.
k	Thermal conductivity
LD	Light-duty
LES	Large eddy simulation
LESI	Lagrangian-Eulerian spark ignition
LLNL	Lawrence Livermore National Laboratory
LT	Low-temperature
LTAT	Low-temperature aftertreatment
LTC	Low-temperature combustion
LTGC	Low-temperature gasoline combustion

mg	Milligram
MIT	Massachusetts Institute of Technology
Mn	Manganese
MOU	Memorandum of Understanding
NH_3	Ammonia
nm	Manometer
NO_x	Oxides of nitrogen
O_2	Oxygen
OBD	On-board diagnostics
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
P	Pressure
PAH	Polycyclic aromatic hydrocarbon
Pd	Palladium
PGM	Platinum group metals
PI	Principal Investigator
PM	Particulate matter
PMI	Particulate matter index
PN	Particle number
PNA	Passive NO_X adsorber
PNNL	Pacific Northwest National Laboratory
Pt	Platinum
Q&A	Question and answer
R&D	Research and development
R_c	Thermal contact resistance
RCM	Rapid compression machine
RD587	88-octane research gasoline
rpm	Revolutions per minute

s	Second
S	Sulfur
SAE	Society of Automotive Engineers
SCO	Selective catalytic oxidation
SCR	Selective catalytic reduction
SCRF	Selective catalytic reduction on filter
Si	Silicon
SI	Spark ignition
SNL	Sandia National Laboratories
ST	SuperTruck
ST1	SuperTruck I
ST2	SuperTruck II
T50	Temperature at which 50% conversion occurs
T90	Temperature at which 90% conversion occurs
TBC	Thermal barrier coating
TCO	Total cost of ownership
TJI	Turbulent jet ignition
TPI	Transient plasma ignition; tuned port injection
TRL	Technology readiness level
TWC	Three-way catalyst
U.S. DRIVE	United States Driving Research for Innovation for Vehicle efficiency and Energy sustainability
USCAR	United States Council for Automotive Research
UW	University of Washington
UW	University of Wisconsin – Madison
VERIFI	Virtual Engine Research Institute and Fuels Initiative
VTO	Vehicle Technologies Office
WHR	Waste heat recovery

Zero-RK	Zero-order reaction kinetics
Zr	Zirconium
ZrO_2	Zirconium dioxide (zirconia)

2. Batteries R&D

To strengthen national security, enable future economic growth, support energy dominance, and increase transportation energy affordability for Americans, the Vehicle Technologies Office (VTO) funds early-stage, high-risk research. The research will generate knowledge that industry can advance to deploy innovative energy technologies to support affordable, secure, reliable and efficient transportation systems across America. VTO leverages the unique capabilities and world-class expertise of the national laboratory system and works with partners across industry and academia to develop new innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures and better powertrains; and energy efficient mobility technologies and systems, including connected and automated vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement. VTO is uniquely positioned to address early-stage challenges due to its strategic research partnerships with industry (e.g., the U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise. These partnerships prevent duplication of effort, focus U.S. Department of Energy (DOE) research on the most critical research and development (R&D) barriers, and accelerate progress. VTO focuses on research that industry either does not have the technical capability to undertake on its own—usually because there is a high degree of scientific or technical uncertainty—or it is too far from market realization to merit sufficient industry emphasis and resources.

The Battery Technologies R&D subprogram funds research programs with partners in academia, national laboratories, and industry, focusing on generating knowledge of high-energy and high-power battery materials and battery systems that can enable industry to significantly reduce the cost, weight, volume and charge time of plug-in electric vehicle (PEV) batteries. The activity supports the development of innovative materials and cell technologies capable of realizing significant cost reductions in two major R&D areas, Advanced Battery Materials R&D, and Advanced Battery Cell R&D. Advanced Battery Materials R&D focuses on early-stage R&D of new lithium (Li)-ion cathode, anode, and electrolyte materials, which account for 50%-70% of PEV battery cost of current technologies. Specifically, this work focuses on the development of new materials that offer a significant improvement in either energy or power and have the potential to achieve the DOE battery cost target of $100/kWh and be capable of charging in 15 minutes or less. Advanced Battery Materials R&D includes the Battery500 research consortium, which is developing “Beyond Li-Ion” technologies. The Battery500 consortium is focusing on designing novel electrode and cell architectures utilizing a Li anode combined with a compatible electrolyte system and high-capacity cathodes and achieving 500 Wh/kg and 1,000 cycles at the lab cell level. R&D also focuses on developing innovative battery materials recycling and reuse technologies to assure sustainability and domestic supply.

The Advanced Battery Cell R&D effort focuses on early-stage R&D of new battery cell technology that contains new materials and electrodes that can reduce the overall battery cost, weight, and volume while improving energy, life, safety, and fast-charging. This R&D area also supports high-fidelity battery performance, life, fast-charging, and safety testing of innovative battery technologies.

Subprogram Feedback

DOE received feedback on the overall technical subprogram areas presented during the 2018 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied.

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year?

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: bat918
Presentation Title: Battery and Electrification R&D Overview
Principal Investigator: Steve Boyd (U.S. Department of Energy)

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:
Yes, the program was covered to meet the needs of this reviewer. The material gave a very good overview of the DOE program and goals, and addressed the issues.

Reviewer 2:
The reviewer stated yes, and commented that the speaker did an excellent job of covering all facets of the battery and electrification R&D efforts. Key challenges in each of the main areas of technology and how they were being addressed by ongoing research was discussed. This reviewer reported that the following were covered: Li-ion and non-lithium battery cell development, including new low cobalt (Co) cathode and intermetallic alloy anode work; electric drive developments at higher voltages and lower costs; and grid issues, including fast charging and cybersecurity. A strong case was made for the need to reduce battery cost and charging time, along with the need to reduce cost and increase efficiency of the traction drive system to ensure large market penetration of electric drive vehicles (EDVs). This reviewer commented that concurrent grid infrastructure needs to support widespread acceptance of electric vehicles (EVs) was also addressed. As far as specific technologies are concerned, the presenter did a particularly good job of covering the wide array of outstanding work in the area of power electronics and motors for vehicle electrification.

Reviewer 3:
The reviewer responded positively and explained that battery life must be properly predicted for projects to be funded in the extreme fast charge Li-ion cell area. This reviewer inquired whether it is possible to develop a degradation model of various battery components so that a predictive model is developed, gets shared with stakeholders, and is tested to validate the developed model.

Reviewer 4:
This reviewer indicated yes and suggested the following strategy adjustments: cost of electric vehicle batteries to less than \$100/kWh and \$6/kW for a 100 kW peak Electric Drive System (EDS); breakout targets by technology areas (e.g., motor, inverter, battery package, controls, and thermal systems); and breakout targets for hybrid electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV), performance EV, and passenger EV.

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Reviewer 1:
The reviewer responded positively and asserted that there is an excellent balance. The presentation addressed the very near-term 2020 to the longer-term 2030 goals, and provided future roadmap indicators for the technologies being reviewed.

Reviewer 2:
This reviewer stated yes. There is an appropriate balance with all three areas well covered, including nearer-term Li-ion battery development and electric drive research focused on cost reduction; mid-term advanced cell battery, high-voltage electric drive, two-phase cooling, multiphysics integration, and grid integration work; and long-term research on extreme fast charging, new materials development, and cybersecurity,

Reviewer 3:
The reviewer commented that there is a need to make some adjustments. Regarding \$6/kW for a 100 kW peak, the reviewer provided the following link to show that HEV sales are slowing (down 19.0%) and strong electric plugged xEVs are increasing (up 46.0%). The reviewer cited an Argonne National Laboratory (ANL) study of

light-duty EDV sales update (http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates). With this in mind, the reviewer stated that future targets need to address the higher power requirements for battery, power electronics, and electric drive. Further, this reviewer noted that 100kW is low as a reference point for the future.

Reviewer 4:

This reviewer indicated yes. For wide bandgap (WBG) devices, the reviewer commented that it is necessary to cover voltage range from 48 volt (V) to 1,700V. The reviewer suggested that development of cost and performance optimized silicon carbide (SiC) power package could be one of the long-term (5 years) research goals.

SiC and gallium nitride (GaN) devices are far smaller than Si devices. Therefore, to keep inverter foot-print optimized and smaller, the reviewer explained that it is necessary to have an application-specific integrated circuit for gate driver circuit that should consist primarily of gate driver circuitry, including isolated power supplies and their watchdogs. The reviewer suggested this could be a mid-term goal and could raise the possibility of wide acceptance of SiC and GaN power converter technology for EVs, HEVs, PHEVs, etc.

Question 3: Were important issues and challenges identified?

Reviewer 1:

This reviewer stated yes, and noted that critical issues included cost reduction, power density increases, increased charging speed, grid integration, cybersecurity, and methods to address range anxiety (e.g., longer battery life and improved infrastructure).

Reviewer 2:

In this overview presentation, the reviewer observed several areas were addressed that impact the future of vehicle electrification. Each area had technical issues and challenges that needed to be addressed, which were done to this reviewer's satisfaction.

Reviewer 3:

The reviewer stated yes, except for how manufacturing will be advanced to support project activities dedicated to achieve 2025 power density and cost targets for electric drive technologies.

Reviewer 4:

This reviewer identified key emerging challenges on the horizon. Firstly, marriage of autonomous with EV means that power management of the low voltage power bus has become safety critical and a challenge in the increased required power for all of the electric actuation and sensing, which could be more than 5kW. Secondly, the reviewer noted that electrical, battery, and component thermal management aspects for extreme fast charging are certainly needed as a future challenge. Finally, this reviewer highlighted the influence of fast charge on graphite (Gr) life, nickel manganese cobalt oxide (NMCxxx), Si, or silicon oxides (SiO_x).

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:

The reviewer responded positively and noted that plans to address critical issues and challenges included cooling and multiphysics integration techniques to permit cost reduction and electric drive power density increases. New charger designs and battery cell materials were also proposed for increased charging speed, along with programs to improve grid integration and infrastructure.

Reviewer 2:

This reviewer stated yes, the plans for addressing the issues and challenges associated with the different technologies were identified. The presentation also provided the funding scheduled to support that work. The reviewer further highlighted that one major and key method identified involved forming collaborative teams that included the various labs and industry.

Reviewer 3:
The reviewer remarked that plans were somewhat identified for addressing issues and challenges, and suggested that plans may need minor or major changes as research progresses to achieve 2025 targets.

Reviewer 4:
This reviewer commented to continue U.S.-based WBG based component development—Tesla now has in its Model 3—and suggested this should be supplied and implemented by somehow leveraging overall domestic capability. The reviewer then referenced battery fast charge as related to electrochemistry and thermals. Regarding battery cost, the reviewer noted low cost chemistry (e.g., lithium manganese oxide [LMO]), and suggested to consider funding original equipment manufacturer (OEM) or supplier-based battery cell prototype equipment to speed learning in domestic locations.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:
Progress from last year was somewhat benchmarked against 2016-2017, as indicated by this reviewer. The trend tended toward progress over a larger timeframe that highlighted steady growth based on technology developments.

Reviewer 2:
This reviewer remarked that progress was somewhat clearly benchmarked against the previous year. For example, the reviewer highlighted a very nice chart showing the reduction in battery cost per year, and suggested that adding a full chart of the major accomplishments in the previous year, the current year, and the planned upcoming year would be nice.

Reviewer 3:
The reviewer stated yes, from a budget perspective, but was unsure whether this could be extrapolated to a technology-based progress. The reviewer suggested it might be worthwhile to have a perspective similar to the Advanced Combustion Systems team, which shows progress in emissions, power, power density, and 0-60 miles per hour vehicle performance over time.

Reviewer 4:
This reviewer reported that 2020 and 2025 targets are quite different.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:
The key goal of the VTO office, as indicated by this reviewer, is to make electric drive vehicles competitive with fossil fuel powered vehicles in all aspects, particularly performance, cost, and overall life. The reviewer remarked that the projects and plans, as outlined, address the technical issues that need to be overcome to meet those goals.

Reviewer 2:
This reviewer stated yes, the projects in this technology area are all aimed at reducing cost, enhancing performance and efficiency, and improving the driving experience (e.g., increasing range, reliability, and security) to promote widespread EV acceptance and thereby minimize carbon (C) emissions and fossil fuel use.

Reviewer 3:

The reviewer indicated that the projects in this technology area somewhat address the broad problems and barriers that VTO is trying to solve, and noted that projects should have a clear pathway for commercialization.

Reviewer 4:

This reviewer responded yes, generally, and recommended a continued focus to get performance up and cost down. One gap the reviewer identified is the marriage of autonomous with EV, which means that power management of the low voltage power bus has become safety critical and a challenge in the increased required power, Automotive Safety Integrity Level D (ASIL D) safety, and power management for all of the electric actuation and sensing. The reviewer added that the required could be even more than 5kW.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:

The reviewer remarked yes; focus is maintained in the most fruitful areas for research. This reviewer observed excellent management at all levels from Steven Boyd, the Program Manager, who is an exceptional leader, to his experienced and expert team, especially Susan Rogers, who leads the electric drive efforts.

Reviewer 2:

This reviewer agreed that the program area appears to be focused, well-managed, and effective in addressing VTO needs. The reviewer reported that the presentation material outlines the areas that will address current, near-term, and future goals. The material covered areas that are needed on the vehicle side as well as much of the infrastructure concerns.

Reviewer 3:

The reviewer responded positively and commented that, in electric machine R&D work, material properties should be modeled to predict how new material will perform for various mission profiles (tow-speed characteristics) required by EVs, HEVs, PHEVs, etc.

Reviewer 4:

This reviewer asserted that an initiative is needed to attract the new and emerging EV companies to participate and suggested that DOE at least make some focused visits to those new companies to collaborate.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:

The reviewer expressed that the projects cover a wide range of topics, but are all complementary and focused toward electric vehicle improvement. Projects focused specifically on critical challenges include those related to design, packaging, thermal management, and reliability of innovative chargers and batteries for fast charging and for the grid infrastructure to support them. This reviewer explained that projects were well supported and had a nice balance of innovation and practicality that permitted significant and achievable progress in a reasonable time.

Reviewer 2:

One area that the reviewer identified was the need to have more visible support and/or input from the U.S. Department of Transportation (DOT). That involvement is undoubtedly there, but it was not clearly presented. The work with batteries was a focus of this reviewer, who indicated that the work in that area continues to push the envelope of understanding the issues and resolving them.

Reviewer 3:
This reviewer asserted that cost is key. Although there could be some more detailed trade-off on power density versus cost and manufacturability to meet cost, the reviewer commented that it will continue to lag in adoption without profitable electrification technology.

Reviewer 4:
This reviewer opined that there is too much focus on electric machine technology and little focus on inverter technology. The reviewer advised that attention to battery technology with a clear focus towards commercialization should be given due attention.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:
The reviewer indicated that the projects are novel and represent innovative ways to approach solutions to the issues involved. Further, this reviewer observed a multi-prong collaborative task force with a single mission, using analytical and testing tools from several labs is being used, which is both novel and innovative.

Reviewer 2:
This reviewer stated yes and highlighted some of the more novel approaches: microporous silicon (Si) anodes; Co-free cathodes; fundamental materials characterization of Li cells for extreme fast charging; use of multiphysics for device and package integration; two-phase cooling; and high voltage, WBG power converters.

Reviewer 3:
The reviewer agreed that these projects represent novel and/or innovative ways to approach these barriers. Alternative and variant cooling methods including phase-change cooling related projects should be funded to realize a power-dense air-cooled power converter, which this reviewer asserted will support adoption of the WBG technologies.

Reviewer 4:
Regarding extreme fast charging, this reviewer explained that, perhaps, the critical enabler of 800V max batteries is not so novel or innovative. Of course, the reviewer continued, this then drives needed work in high voltage (HV) power electronics and electric drives.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:
This reviewer stated yes; each of the projects has identified leaders in the field for collaboration. The level of industrial, academic, and government laboratory interactions in this program is impressive and the partners chosen are recognized experts.

Reviewer 2:
The reviewer responded positively and asserted that vehicle OEMs, battery manufacturers, national laboratories, and parts manufacturers for the battery manufacturers are all involved.

Reviewer 3:
This reviewer opined that industry, university, and DOE lab partnership should be encouraged to solve problems perceived as difficult and/or impossible.

Reviewer 4:
The reviewer commented that, generally, getting major OEMs is key. However, the reviewer indicated that there could be some sort of initiative needed to attract new and emerging EV companies to participate. This reviewer suggested that DOE at least make some focused visits to those new companies to collaborate.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:

The reviewer responded positively and observed regular, arranged meetings with updates that are provided. This reviewer further commented on dynamic direction and support that is delivered based on progress.

Reviewer 2:

This reviewer stated yes and suggested that industry, university, and DOE national laboratory partnerships should be further encouraged to solve problems perceived as difficult and/or impossible.

Reviewer 3:

Generally, the reviewer reported significant evidence of strong collaboration with industry and academia, as well as other government laboratories, though it depends on the project. Each partner is supplying a key appropriate aspect of each project, whether that is new materials, design expertise, modeling expertise, components for test, or facilities.

Reviewer 4:

The reviewer noted a basic model focus on having OEMs and suppliers build functional prototypes. This reviewer also observed labs and universities on materials, basic research, and studies.

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:

The reviewer remarked that gaps have been identified, but are a risk level that allows them to exist until the key items are addressed. This reviewer added that the focus has to be on areas that will drive success rather than areas that may have some limited value.

Reviewer 2:

Regarding the design for "Giga-Watt-Hr" (GWh) production of battery cells and packs, this reviewer commented that electrochemistry is important, but will need the balance with manufacturing at large scale to be a factor. Although reducing Co and other materials saves money, so does a more efficient manufacturing technique.

Reviewer 3:

This reviewer indicated that it seems like Li-ion batteries are tracking quite well with the desired trends for cost reduction, as this is happening year after year. In the category of beyond Li-ion projects, there should be some focus to improve Li-Ion technology too; this is needed for large scale adoption of EVs. The reviewer opined that car drivers still have battery reliability in mind when they hit car dealers to buy an EV.

Reviewer 4:

The reviewer recommended other areas to investigate, including the following: three dimensional (3-D) packaging, including additive manufacturing; electro-thermal-mechanical-reliability co-design; high voltage thin film insulators; and new WBG semiconductors (e.g., gallium oxide, diamond).

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:

The reviewer asserted that key topics to make this technology reach stated goals are being addressed.

Reviewer 2:

This reviewer commented that future targets need to address the higher power requirements for battery, power electronics, and electric drive, and further highlighted that 100 kW is low as a future reference point.

Reviewer 3:
According to this reviewer, some attention should be given to enabling technologies for inverters, such as packaging material; thermal management materials, including advanced cooling technologies for inverters; inverter interconnects; motor; and connectors, etc.

Reviewer 4:
The reviewer referenced prior comments.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:
This reviewer recommended ensuring state of charge (SOC) and state of health (SOH) algorithms during these events as related to extreme fast charging.

Reviewer 2:
The reviewer suggested other potential areas that may need funding to meet the overall goal of vehicle electrification.

Reviewer 3:
The reviewer commented that eliminating resistive contacts within an inverter and between motor and inverter should be given due consideration. The reviewer explained that, often, Electric Drive (ED) fails or life of ED reduces due to heating of various inter connects within ED system.

Reviewer 4:
This reviewer referenced prior comments.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:
The involvement of the different national laboratories and OEMs has allowed for a multitude of counselors to be involved in evaluating and suggesting all viable approaches that this reviewer could envision.

Reviewer 2:
The program’s current approach was described by this reviewer as well on track.

Reviewer 3:
This reviewer was unable to offer any quality ideas.

Reviewer 4:
The reviewer remarked that capturing requirements early should be encouraged for each project. Further, this reviewer suggested accomplishing this by identifying a specific application of underlying technology being developed through DOE-VTO funding. Often, R&D work goes somewhat satisfactorily; however, research faces the valley of death due to lack of adoption when research outcomes fall short in addressing application needs. The reviewer opined that this can be addressed by encouraging industry partnership with a commitment to demonstrating technology in an identified application.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:
The reviewer commented that this presentation did exactly what was needed—it gave a very good overview of the programs involved, their tasks, goals, and accomplishments. This presentation was also effective as it highlighted some of the key issues that must be overcome.

Reviewer 2:
The reviewer stated none.

Reviewer 3:
Continuing focus on the most critical constraints to a widespread market penetration of electric vehicles (i.e., cost, range, and reliability) was recommended by this reviewer.

Reviewer 4:
This reviewer suggested that increased involvement of industry reviewers should be considered during selection of projects for DOE-VTO funding. If possible, university and DOE national laboratory projects should have industry advisors with application oriented mindsets. Otherwise, continued this reviewer, DOE-VTO funded R&D work runs the risk of falling into the valley of death.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0*). In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 2-1—Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat049	Tailoring Integrated Layered- and Spinel Electrode Structures for High-Capacity Lithium-Ion Cells †	Michael Thackery (ANL)	2-19	3.33	3.17	3.50	3.17	**3.25**
bat052	Design of High-Performance, High-Energy Cathode Materials †	Marca Doeff (LBNL)	2-22	3.17	3.17	3.33	2.83	**3.15**
bat056	Development of High-Energy Cathode Materials †	Jason Zhang (PNNL)	2-25	3.50	3.17	3.50	2.67	**3.23**
bat085	Interfacial Processes—Diagnostics †	Robert Kostecki (LBNL)	2-29	3.40	3.40	3.40	3.50	**3.41**
bat106	High-Capacity, Multi-Lithium Oxide Cathodes and Oxygen Stability †	Jagit Nanda (ORNL)	2-34	3.17	3.00	3.17	3.33	**3.10**
bat164	Thick, Low-Cost, High-Power Lithium-Ion Electrodes via Aqueous Processing †	Jianlin Li (ORNL)	2-37	3.75	3.75	3.50	3.00	**3.63**
bat168	Process Development and Scale-Up of Critical Battery Materials—Continuous Flow-Produced Materials	Krzysztof Pupek (ANL)	2-39	3.17	3.33	3.33	3.33	**3.29**
bat183	In Situ Solvo-Thermal Synthesis of Novel High-Capacity Cathodes †	Feng Wang (BNL)	2-42	3.33	3.33	3.67	3.33	**3.38**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat220	Addressing Heterogeneity in Electrode Fabrication Processes †	Dean Wheeler (Brigham Young U.)	2-45	3.67	3.33	3.33	3.33	**3.42**
bat230	Nanostructed Design of Sulfur Cathode for High Energy Lithium-Sulfur Batteries †	Yi Cui (Stanford University)	2-48	3.70	3.50	3.40	3.40	**3.53**
bat232	High Energy Density Electrodes via Modifications to the Inactive Components and Processing Conditions †	Vincent Battaglia (LBNL)	2-53	3.00	3.00	3.25	3.00	**3.03**
bat235	Characterization Studies of High-Capacity Composite Electrode Structures †	Jason Croy (ANL)	2-55	3.50	3.33	3.50	3.00	**3.35**
bat240	High-Energy Anode Material Development for Lithium-Ion Batteries, Cary Hayner, Sinode Systems †	Cary Hayner (Sinode Systems)	2-58	3.13	2.88	3.50	2.67	**2.99**
bat241	Advanced High-Performance Batteries for Electric Vehicle (EV) Applications †	Ionel Stefan (Amprius)	2-61	3.38	3.63	2.50	3.25	**3.38**
bat247	High-Energy Lithium Batteries for Electric Vehicles †	Herman Lopez (Envia Systems)	2-64	3.13	3.38	3.25	2.83	**3.23**
bat252	Enabling High-Energy, High-Voltage Lithium-Ion Cells for Transportation Applications: Electrochemistry and Evaluation	Daniel Abraham (ANL)	2-67	3.33	3.33	3.33	3.33	**3.33**
bat253	Enabling High-Energy, High-Voltage Lithium-Ion Cells for Transportation Applications: Theory and Modeling	Hakim Iddir (ANL)	2-70	3.67	3.67	3.67	3.50	**3.65**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat254	Enabling High-Energy, High-Voltage Lithium-Ion Cells for Transportation Applications: Materials Characterization	John Vaughey (ANL)	2-73	3.33	3.33	3.50	3.17	**3.33**
bat263	Electrodeposition for Low-Cost, Water-Based Electrode Manufacturing †	Stuart Hellring (PPG Industries)	2-76	3.17	3.33	3.17	3.17	**3.25**
bat264	Lithium-Ion Battery Anodes from Electrospun Nanoparticles/Conducting Polymer Nanofibers †	Peter Pintauro (Vanderbilt U.)	2-79	3.50	3.17	3.00	3.00	**3.21**
bat266	Co-Extrusion (CoEx) for Cost Reduction of Advanced High-Energy and High-Power Battery Electrode Manufacturing †	Ranjeet Rao (PARC)	2-82	3.50	3.00	3.33	3.00	**3.17**
bat269	An Integrated Flame-Spray Process for Low-Cost Production of Battery Materials †	Chad Xing (U. of Missouri)	2-85	3.00	2.33	3.00	2.67	**2.63**
bat273	Composite Electrolyte to Stabilize Metallic Lithium Anodes †	Nancy Dudney (ORNL)	2-88	3.00	3.13	3.13	3.00	**3.08**
bat282	Development of High-Energy Lithium-Sulfur Batteries †	Jun Liu (PNNL)	2-92	3.50	3.30	3.40	3.13	**3.34**
bat293	A Closed-Loop Process for End-of-Life Electric Vehicle Lithium-Ion Batteries †	Yan Wang (WPI)	2-96	3.38	3.63	3.50	3.33	**3.51**
bat296	Development and Validation of a Simulation Tool to Predict the Combined Structural, Electrical, Electrochemical, and Thermal Responses of Automotive Batteries †	Chulheung Bae (Ford)	2-99	3.40	3.50	3.70	3.40	**3.49**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat298	Efficient Simulation and Abuse Modeling of Mechanical-Electrochemical-Thermal Phenomena in Lithium-Ion Batteries †	Shriram Santhanagopalan (NREL)	2-103	3.50	3.60	3.60	3.40	**3.55**
bat299	Microstructure Characterization and Modeling for Improved Electrode Design †	Kandler Smith (NREL)	2-108	3.70	3.70	3.50	3.63	**3.67**
bat300	Enhancement and Deployment of VIBE, the Open Architecture Software (OAS) Environment †	Srikanth Allu (ORNL)	2-113	3.60	3.50	3.60	3.40	**3.53**
bat301	Experiments and Models for the Mechanical Behavior of Battery Materials †	Sergiy Kalnaus (ORNL)	2-117	3.50	3.50	3.40	3.50	**3.49**
bat302	Microstructure Imaging and Electrolyte Transport Property Measurements for Mathematical Modeling †	Venkat Srinivasan (ANL)	2-121	3.40	3.20	3.50	3.30	**3.30**
bat303	Exploring How Electrode Structure Affects Electrode-Scale Properties Using 3-D Mesoscale Simulations †	Scott Roberts (SNL)	2-125	3.50	3.50	3.40	3.60	**3.50**
bat307	Discovery of High-Energy Lithium-Ion Battery Materials †	Wei Tong (LBNL)	2-129	3.17	3.33	3.33	3.00	**3.25**
bat310	Advancing Solid-State Interfaces in Lithium-Ion Batteries †	Nenad Markovic (ANL)	2-132	3.30	3.20	3.30	3.00	**3.21**
bat312	Advanced Lithium-Ion Battery Technology: High-Voltage Electrolyte †	Joe Sunstrom (Daikin)	2-136	3.10	3.20	2.80	3.00	**3.10**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat319	Advanced Microscopy and Spectroscopy for Probing and Optimizing Electrode-Electrolyte †	Shirley Meng (UC-San Diego)	2-140	3.70	3.30	3.40	3.30	**3.41**
bat321	Solid-State Inorganic Nanofiber Network-Polymer Composite Electrolytes for Lithium Batteries †	Nianqiang Wu (West Virginia U.)	2-144	3.60	3.40	3.20	3.30	**3.41**
bat322	High Conductivity and Flexible Hybrid Solid-State Electrolyte †	Eric Wachsman (U. of Maryland)	2-149	3.30	3.50	3.50	3.30	**3.43**
bat323	Self-Forming Thin Interphases and Electrodes Enabling 3-D Structured High Energy Density Batteries †	Glenn Amatucci (Rutgers U.)	2-153	3.50	3.50	3.10	3.50	**3.45**
bat326	Self-Assembling and Self-Healing Rechargeable Lithium Batteries †	Yet Chiang-Ming (MIT)	2-158	3.40	3.30	3.50	3.50	**3.38**
bat328	Dendrite-Growth Morphology Modeling in Liquid and Solid Electrolytes †	Yue Qi (Michigan State U.)	2-163	3.60	3.60	3.50	3.70	**3.60**
bat329	Understanding and Strategies for Controlled Interfacial Phenomena in Lithium-Ion Batteries and Beyond †	Perla Balbuena (Texas A&M U.)	2-168	3.40	3.30	3.70	3.40	**3.39**
bat330	Electrochemically Responsive, Self-Formed, Lithium-Ion Conductors for High-Performance Lithium-Metal Anodes †	Donghai Wang (Penn State U.)	2-173	3.50	3.30	3.30	3.40	**3.36**
bat332	High Electrode Loading Electric Vehicle Cell †	Mohamed Taggougui (24M Technologies)	2-177	3.63	3.63	3.25	3.13	**3.52**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat344	Electrolyte Reactivity and Its Implication for Solid-Electrolyte Interface (SEI) Formation	Kristin Persson (LBNL)	2-180	3.42	3.58	3.58	3.33	**3.51**
bat345	Chemical Reactivity of Silicon at the Surface	Gabe Veith (ORNL)	2-185	3.42	3.42	3.58	3.25	**3.42**
bat346	Spectroelectrochemistry of Silicon Model Electrodes	Robert Kostecki (LBNL)	2-190	3.58	3.67	3.50	3.33	**3.58**
bat347	Surface Analysis of the Silicon Solid-Electrolyte Interface (SEI)	Chunmei Ban (NREL)	2-194	3.33	3.33	3.33	3.17	**3.31**
bat348	Synthesis and Stability of Lithium Silicate and Its Interaction with the Solid-Electrolyte Interface (SEI)	Chris Apblett (SNL)	2-194	3.25	3.08	3.25	3.33	**3.18**
bat349	Research Facilities Support	Kyle Fenton (SNL)	2-204	3.33	3.42	3.50	2.50	**3.29**
bat350	Electrode Characterization and Analysis	Daniel Abraham (ANL)	2-209	3.25	3.50	3.63	3.25	**3.42**
bat351	Active Particle Studies	Baris Key (ANL)	2-212	3.38	3.25	3.38	3.13	**3.28**
bat352	Active Materials Advancements	Zhengcheng Zhang (John) (ANL)	2-215	3.38	3.38	3.63	3.13	**3.38**
bat353	Crucial Supporting Materials Advancements	Gao Liu (LBNL)	2-218	3.50	3.25	3.38	3.38	**3.34**
bat355	Development of High-Performance Lithium-Ion Cell Technology for Electric Vehicle Applications †	Keith Kepler (Farasis Energy)	2-221	3.33	3.50	3.83	3.33	**3.48**
bat356	Lithium-Ion Cell Manufacturing Using Directly Recycled Active Materials †	Mike Slater (Farasis Energy)	2-225	3.50	3.50	3.50	3.33	**3.48**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat357	Thicker Cathode Coatings for Lithium-Ion Electric Vehicle Batteries †	Stuart Hellring (PPG Industries)	2-228	3.33	3.33	3.50	3.33	**3.35**
bat358	Advanced Separators for Vehicle Lithium Battery Applications †	Junqing Ma (Celgard)	2-231	3.00	2.67	3.33	2.83	**2.85**
bat359	Status and Challenges of Electrode Materials for High Energy Cells	Stanley Whittingham (Binghamton U.)	2-234	3.60	3.40	3.60	3.40	**3.48**
bat360	Overview and Synthesis of High-Nickel Nickel Manganese Cobalt Oxide (NMC) Cathodes	Arumugam Manthiram (UT-Austin)	2-239	3.70	3.80	3.60	3.60	**3.73**
bat361	Lithium-Sulfur Batteries: From Materials Understanding to Device Integration	Yi Cui (Stanford University)	2-243	3.42	3.67	3.67	3.50	**3.58**
bat362	Lithium-Metal Anodes: Problems and Multiple Solutions Based on Hosts, Interphase, and Electrolytes	Jun Liu (PNNL)	2-247	3.90	3.90	3.80	3.70	**3.86**
bat363	Understanding Performance Limitations in Thick Electrodes, Ping Liu	Ping Liu (UC-San Diego)	2-251	3.40	3.30	3.40	3.20	**3.33**
bat364	Coatings for Cathode and Separator	Jihui Yang (U. of Washington)	2-255	3.50	3.70	3.50	3.50	**3.60**
bat365	Stabilizing Lithium-Metal Anode by Interfacial Layer	Zhenan Bao (Stanford University/ SLAC)	2-260	3.30	3.40	3.20	3.20	**3.33**
bat366	Advanced Imaging and Spectroscopic Study of Electrochemically Deposited Lithium Metal	Shirley Meng (UC-San Diego)	2-264	3.60	3.50	3.60	3.30	**3.51**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
bat367	Integrated Characterization Studies of Battery500 Consortium	Xiao Yang-Qing (BNL)	2-269	3.60	3.60	3.50	3.50	**3.58**
bat368	Battery500 Integrated Cell Diagnostics and Modeling to Identify Critical Gaps in Achieving High Cycle Life	Eric Dufek (INL)	2-274	3.25	3.13	3.25	3.00	**3.16**
bat369	High Energy Rechargeable Lithium-Metal Cells: Fabrication and Integration	Jie Xiao (PNNL)	2-278	3.60	3.30	3.60	3.40	**3.43**
bat370	Advanced Diagnostics of Nickel-Rich, Layered-Oxide Secondary Particles	Chueh, William C. (Stanford University/ SLAC)	2-283	3.38	3.38	3.13	3.25	**3.33**
Overall Average				**3.42**	**3.39**	**3.42**	**3.27**	**3.39**

† Denotes a poster presentation.

Presentation Number: bat049
Presentation Title: Tailoring Integrated Layered and Spinel Electrode Structures for High-Capacity Lithium-Ion Cells
Principal Investigator: Michael Thackery (Argonne National Laboratory)

Presenter
Jason Croy, Argonne National Laboratory

Reviewer Sample Size
A total of three reviewers evaluated this project.

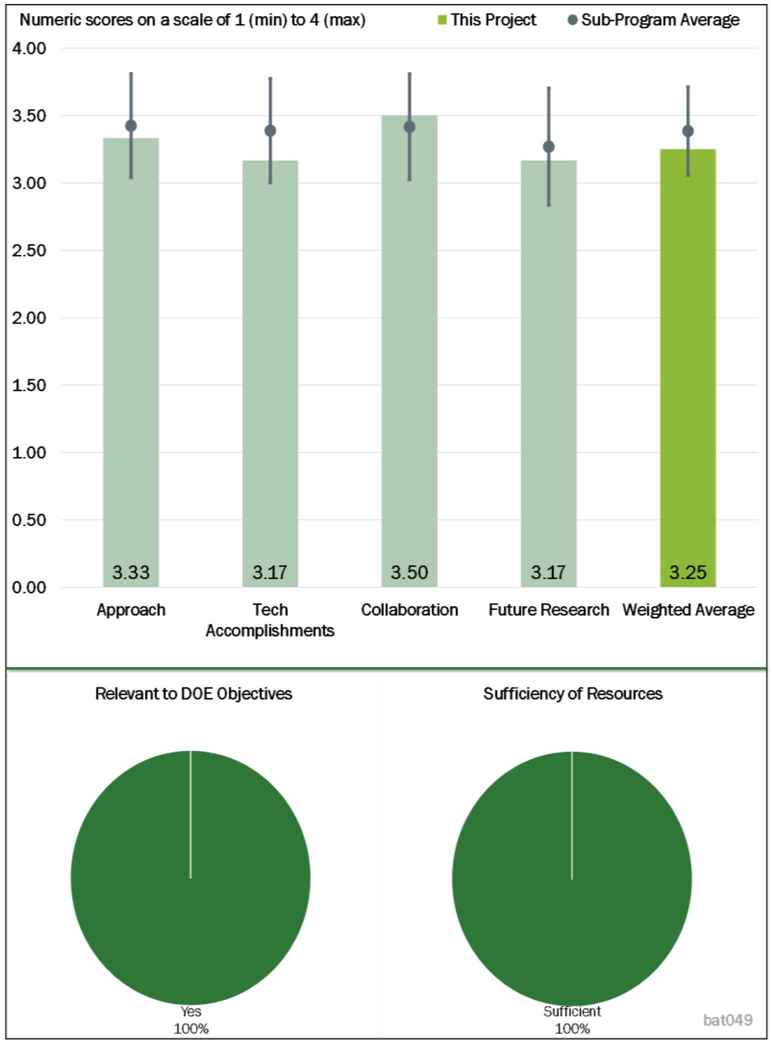

Figure 2-1 - Presentation Number: bat049 Presentation Title: Tailoring Integrated Layered and Spinel Electrode Structures for High-Capacity Lithium-Ion Cells Principal Investigator: Michael Thackery (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer stated that the project team reported the approaches and results of the optimization of cathode material, manganese (Mn)-rich layered-layered-spinel (LLS). The reviewer remarked that the potential merits of high capacity (high energy density) and low-cost have been demonstrated. The reviewer said that the stabilizing surface treatment with the approaches of chemical modification, novel electrolyte, etc., has been successfully addressed. The reviewer remarked that excellent progress has been made in designing the new cathode materials.

Reviewer 2:
The reviewer stated that the project optimizes the performance of structurally-integrated “composite” electrode structures with a prime focus on LLS materials and designs effective strategies to mitigate surface degradation of integrated structures to improve and maintain their stability and rate capability when charged to high potentials [i.e., 4.5V to 4.6V]. The reviewer also noted that this project aims to enable high first-cycle efficiencies, enhanced rate performance, and relative stability.

Reviewer 3:
The reviewer expressed that this project has a generally good approach to the discovery and validation of LLS cathode materials. The reviewer stated that based on the history of the project team, the reviewer is confident in the quality of the work that underlies this project, but pointed out that the project’s research summary slides are relatively vague (i.e., on the surface modification and the role of electrolytes on stability). The reviewer would have appreciated additional explanation into the materials synthesis methods and the selection of LLS

compositions or modifications. During a discussion between the reviewer and the project team during the poster session, it was made clear that the spinel is meant to stabilize the structure. The reviewer further noted, however, the distribution and integration of the spinel is quite challenging and may not be controllable enough to achieve appropriate synthetic scale-up. The reviewer said the application of surface stabilization strategies (i.e., with alumina or other coatings) and electrolyte optimization is warranted and, as the results show, effective.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that a new Mn-rich LLS was proposed. The reviewer remarked that technical approaches to address the challenge of capacity fading have been successfully performed, and that significant progress has been made since the last review meeting.

Reviewer 2:

The reviewer stated that this project has made good progress towards developing strategies to improve the performance of LLS cathodes. The reviewer also noted that standard strategies of thermal treatments, electrolyte optimization, and particle coating are implemented to assist in the stability of the particles. The reviewer pointed out that the extra stabilization strategies seem to compensate for known degradation mechanisms of the LLS including the dissolution of Mn. The reviewer commented that for future reference, a state-of-the-art cathode material such as NMC-622 or NMC-811 should be used to demonstrate the benefit of these materials to energy density, rather than using NMC-532, despite NMC-532 being closer in stoichiometry to the LLS.

Reviewer 3:

The reviewer observed that this project develops Mn-rich LLS composition and that the first-cycle efficiency is approximately 95%. The reviewer stated that small-scale testing against NMC-532 cathodes shows that the LLS materials are promising options. The reviewer noted that the project team is using lithium titanate (LTO) as the anode mitigates deleterious side reaction. The reviewer also noted that testing of LLS baseline in LLS//LTO configurations verifies stability of cathode to Li extraction and insertion where the LLS is the source of Li. The reviewer commented that about 350 cycles of approximately 180 milliampere-hours/gram (mAh/g), 4.45V Li/ lithium ion (Li+) achieved in LLS//LTO coin cells before around a 20% loss. The reviewer noted that the project team found critical surface issues and that the project team did the chemical modification/electrolyte study to stabilize the surface. The reviewer summarized that about 800 (Watt-hours per kilogram oxide (Wh/kg_{oxide}) was demonstrated for 100 cycles to 4.5V. However, the project team needs to demonstrate bigger cell performance and check if LTO has any gassing issue.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that a team at ANL leads the work and there is collaboration among seven total partners. The reviewer stated that multiple research results were achieved through the collaborative work, such as stabilization of material surface with electrolytes and full cell test.

Reviewer 2:

The reviewer remarked that the collaboration across the project team appears effective. The reviewer also stated that there is a dearth of information as to which collaborator provides what project work.

Reviewer 3:

The reviewer noted that the project team works with different teams at ANL, Northwestern University, and Oak Ridge National Laboratory (ORNL).

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the future project plan utilizes standard strategies for addressing particle and electrode stability, but it is somewhat vague. The reviewer would like to see greater focus on the effect of spinel integration, including synthetic conditions, on cycle life, and its stability within the LLS structure.

Reviewer 2:
The reviewer suggested more detailed cost analysis to compare with NMC-532 and to provide more evidence that this is a low-cost cathode material. The reviewer also suggested that future work to add to the understanding of the capacity fading mechanism of the large pouch cell with this new cathode material, so that the continued improvements can be addressed.

Reviewer 3:
The reviewer remarked that the proposed future work is in a logical manner.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer summarized that the DOE objectives require the cathode materials to be high safety, high energy density, and low cost. The reviewer noted that the Mn-rich LLS cathode material potentially matches well with DOE targets.

Reviewer 2:
The reviewer noted that that the project goal was to synthesize and stabilize LLS structures that could meet DOE energy density and cycle life goals. The reviewer confirmed that least in theory, this strategy could achieve cathode capacities that are competitive or greater than the state-of-the-art, but they require additional development—particularly to achieve cycle lifetimes that are industrially relevant.

Reviewer 3:
The reviewer remarked that the Mn-rich electrodes are being developed in order to realize competitive alternatives to nickel (Ni)/Co-rich chemistries. The reviewer stated the three-component, Mn-rich, “LLS” composite cathodes have been designed that show competitive oxide energies as compared with an industrial NMC-532. The reviewer commented that combined approaches of new surface materials and electrolyte formulations have demonstrated approximately 800 Wh/kg oxide energy densities in full-cell configurations using Gr anodes.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that the project is led by ANL and parted with CNM, Northwestern University, ORNL, and others. The reviewer said the resources provide sufficient capabilities of synthesis, analysis, and evaluation.

Reviewer 2:
The reviewer stated that the resources are sufficient for the project.

Reviewer 3:
The reviewer noted that the project achieved one milestone and that the other two milestones are close to complete and ongoing.

Presentation Number: bat052
Presentation Title: Design of High-Performance, High-Energy Cathode Materials
Principal Investigator: Marca Doeff (Lawrence Berkeley National Laboratory)

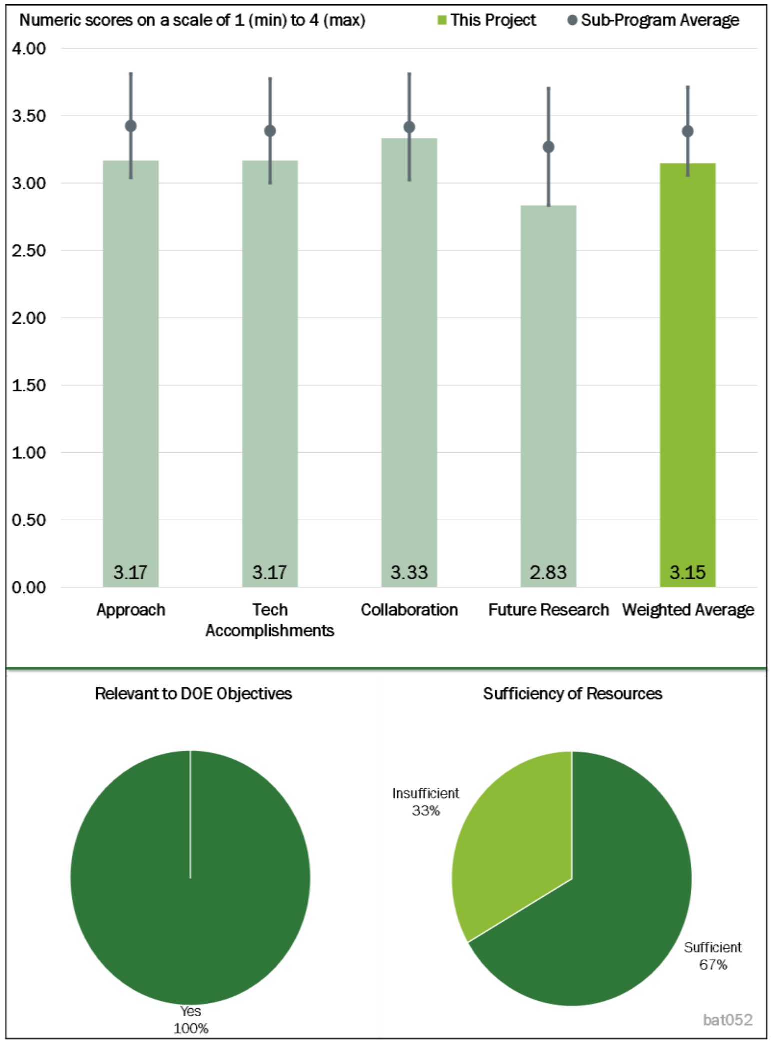

Figure 2-2 - Presentation Number: bat052 Presentation Title: Design of High-Performance, High-Energy Cathode Materials Principal Investigator: Marca Doeff (Lawrence Berkeley National Laboratory)

Presenter
Marca Doeff, Lawrence Berkeley National Laboratory

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer remarked that high-Ni NMCs have been considered as the promising cathode materials for Li-ion batteries; however, their thermal stability and structural evolution has not been fully understood. The reviewer stated that the project team used several advanced techniques to understand those fundamental issues.

Reviewer 2:
The reviewer stated that the present work uses synchrotron techniques and microscopy to understand thermal and high voltage cycling behavior of NMCs. The reviewer noted that the project team used this information to develop strategies to improve behavior and understand the effects. The reviewer said the go/no-go decision is focused on core-shell composites made by spray pyrolysis. The reviewer commented that the project team will explore alternative synthesis approaches.

Reviewer 3:
The reviewer stated that the degree of characterization of NMC chemistry is very thorough, particularly related to the effects of de-lithiation and high temperature. The reviewer noted that experiments that compare surface versus bulk states are particularly valuable (e.g., full-field transmission X-ray microscope [TXM] mapping of Ni content and soft X-ray absorption spectroscopy [XAS]). The reviewer commented that in previous years, the project has looked at the differences between chemical and electrochemical lithiation, finding some discrepancy in surface reconstruction. The reviewer remarked that this year, most work appears to have been conducted on chemically de-lithiated samples, so there remains some question about the relevance of these surface studies to application in a practical format. The reviewer also stated that the goals of this project are to develop high-energy and long cycle life cathode materials, and there have been no performance studies executed this year to emphasize the relevance of the microscale materials transformations. The reviewer asked

about the relevance of studying thermal behavior at temperatures as high, or higher than, 250° Celsius (C) and stated these temperatures are unlikely in battery cell environments. The reviewer remarked that although these findings are admirable as a fundamental study of thermodynamics and kinetics, there is little connection between the phenomena studied and design criteria for more robust cathode materials.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the project team has applied both ex situ and in situ techniques of X-ray powder diffraction (XRD), XAS, soft XAS, and transmission electron microscopy (TEM) to understand the structural evolution of NMCs, which is very important design reliable method to stabilize those cathode materials in a de-lithiated state.

Reviewer 2:

The reviewer remarked that this project studied NMC-622 and NMC-811 chemical de-lithiation, performed NMC-622 and NMC-811 in situ heating experiments, compared bulk thermal stabilities, etc. The reviewer noted that the project team found the thermal stability decreases as Li decreases and Ni rises. The reviewer remarked that the surface sensitive techniques reveal a more complex behavior than the bulk techniques of XAS and XRD.

Reviewer 3:

The reviewer said, as usual from the project team, the wealth of data and thoroughness of the characterization is excellent. However, because the goal of the project is to provide insight into the performance of NMCs, it is unfortunate that no electrochemical results are shown. Furthermore, the objectives mention high voltage behavior and variants of NMC materials in doped or graded compositions, but there were no results on these. The reviewer commented that because this project ends this year, the reviewer would have liked to see experimental progress on the design of more robust NMC materials.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the project team worked with Stanford Synchrotron Radiation Lightsource (SSRL) and Brookhaven National Laboratory (BNL).

Reviewer 2:

The reviewer stated that the extensive and varied characterization results emphasize that there is a strong collaborative aspect to this project. The reviewer noted that however, there is not enough explanation of the particular contributions of individual project collaborators.

Reviewer 3:

This work was collaborated within several groups in Lawrence Berkeley National Laboratory (LBNL) and BNL. The reviewer did not see how much the contribution from each group was to finish this work.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that for the rest of fiscal year (FY) 2018, the project team will finish up the thermal characterization of NMC-811 and investigate the effects of titanium (Ti)-substitution on phase behavior, thermal stability, and electrochemical behavior. The reviewer noted that new proposals for work on cathode materials and Na-ion battery materials are being prepared now.

Reviewer 2:

The reviewer stated that the project is near completion, but several objectives have yet to be met. The reviewer said that continuing the current studies with the Ti-substituted material and finishing the analysis of thermal treatment with the same methods should be sufficient.

Reviewer 3:

The reviewer remarked that the project team proposed to finish up the thermal characterization of NMC-811 and Ti-substituted NMCs. The reviewer also believed this direction is important and should be continued. The reviewer remarked that the research of the sodium (Na)-ion is not very interesting, as this battery system would offer higher energy density and cannot be used in EVs, at least in the near future.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said obtaining a fundamental understanding of material transformations in NMCs is very supportive of DOE goals.

Reviewer 2:

The reviewer expressed that Ni-rich NMCs are key cathode materials for high-performance Li-ion batteries. The reviewer said this project provides further understanding of the structural evolution of those cathode materials under a de-lithiated state, which is very important to improve the design of robust electrode materials.

Reviewer 3:

The reviewer commented that the presented work demonstrates the trend (layered→ disordered→spinel→M_3O_4→spinel→MO (rock salt) as the temperature is raised. The reviewer said surface sensitive techniques reveal a more complex behavior than the bulk techniques of XAS and XRD.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted this research and this project applied many advanced techniques, such as in situ or ex situ XRD, XAS, soft XAS, and TEM, to perform the fundamental study.

Reviewer 2:

The reviewer commented that given this project is close to the end, the project team only completed four out of eight milestones. The reviewer said the project’s no-go decision was on core-shell composites made by spray pyrolysis.

Reviewer 3:

The reviewer said that the resources are sufficient, but could be better utilized to focus on material performance and the design of new robust cathode materials.

Presentation Number: bat056
Presentation Title: Development of High-Energy Cathode Materials
Principal Investigator: Jason Zhang (Pacific Northwest National Laboratory)

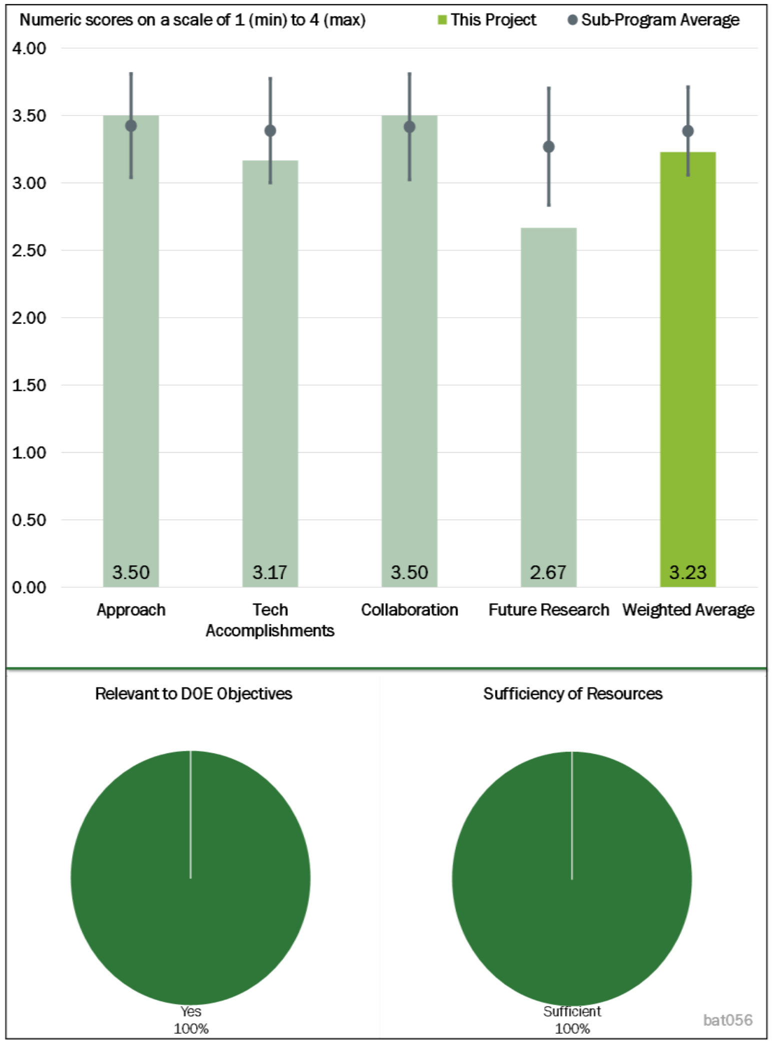

Figure 2-3 - Presentation Number: bat056 Presentation Title: Development of High-Energy Cathode Materials Principal Investigator: Jason Zhang (Pacific Northwest National Laboratory)

Presenter

Jason Zhang, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that high-Ni NMCs have been demonstrated as high-energy density cathode materials for next-generation Li+ batteries. The reviewer noted that the fast capacity fading has been one of the key barriers to commercialize those electrode materials. The reviewer commented that the project team applied different synthetic approaches to address those technical difficulties and showed very impressive improvement.

Reviewer 2:

The reviewer remarked that the technical approach to this project is straightforward and individual efforts complement each other nicely. The reviewer commented, at first, the project team synthesizes high Ni NMC materials and evaluates the importance of annealing temperature on primary particle size. The reviewer noted that using primarily electrochemical methods and microscopy, intraparticle cracking is found to be a factor in cycle life degradation—as discussed in the community at large over the past few years. The reviewer said this issue is tackled by evaluating an optimized electrolyte formulation, and by doping of particles with aluminum (Al) or zirconium (Zr). The reviewer commented that both methods are somewhat successful in limiting cracking of secondary particles, and characterizing their effects on performance is thorough. The reviewer stated that while progress has been good, additional analysis of materials using chemical methods such as spectroscopic or diffraction to understand interface structure would benefit this work.

Reviewer 3:

The reviewer stated that this project uses a co-precipitation method to synthesize the Ni-rich NMC cathode with different compositions and employs the optimized electrolyte and additive to enhance the cycling performance and electrode and electrolyte interface stability. The reviewer remarked that the project team optimized the doping elements and did the surface treatment to enhance the stability of Ni-rich NMC cathode materials. In addition, the project team applied advanced techniques to investigate the capacity improvement mechanism of solid electrolyte surface modification. The reviewer noted that although improved performance of Ni-rich NMC cathodes can be achieved in coin cells, their performance in Gr and NMC pouch cells still need to be further studied.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that this project improved the cycling performance and the interface stability of NMC cathode by using a novel additive. The reviewer remarked that the project team used an optimized electrolyte to achieve excellent 500 cycling performance of NMC cathode and Al doping to enhance the NMC cathode and electrolyte interface stability. In addition, the project team combined uniform coating and a novel additive to enhance the cycling stability of the NMC cathode. The reviewer cautioned that the project team needs to demonstrate Ni-rich NMC performance to reach 200 mAh/g and 80% capacity retention after 300 cycles by the end of the program.

Reviewer 2:

The reviewer noted the report discussed the effects of the electrolyte, Al doping and zirconium dioxide (ZrO_2) coating. However, the reviewer suggested a systematic study, which means the optimization of each parameter is critical for fully understanding the function of every approach.

Reviewer 3:

The reviewer remarked that the project is focused and the results are clearly beneficial to understanding degradation mechanisms in high-Ni NMCs, as well as mitigation strategies. The reviewer said the selection of a non-commercial NMC stoichiometry of NMC-76 is alright, but using a formulation closer to state-of-the-art NMC-811 would be better. The reviewer also believed this project could be more ambitious in its objectives toward a fundamental understanding of interface degradation of high-Ni-NMCs. The reviewer said, particularly, there are other mechanisms beyond particle cracking that are known to lead to capacity fade, including gassing at high voltages and cathode-electrolyte interphase (CEI) instability. The reviewer noted that investigating Al and Zr doping is interesting, but a better understanding of why we would use either Zr, Al, or other dopants (i.e., atomic size, valence, etc.) would aid in the design of more stable materials.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer pointed out this work is led by Pacific Northwest National Laboratory (PNNL) and collaborated among several partners from ANL, BNL, etc. The reviewer remarked the collaboration is excellent.

Reviewer 2:

The reviewer said collaboration among the team appears strong; however, individual collaborator contributions are not explicitly noted.

Reviewer 3:

The reviewer noted that ANL provides standard NMC cathode and materials for testing, Missouri University of Science and Technology is doing atomic layer deposition (ALD) coating, BNL performs in situ XRD on electrode materials, and Army Research Laboratory (ARL) is studying electrolytes and additives.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer suggested that the project team should also work on optimizing doping and coating. The reviewer also suggested that the project team work on understanding how much doping is needed for the best performance. The reviewer also suggested working to determining what the thickness of the coating yields the best performance.

Reviewer 2:

The reviewer cautioned that developing a low-cost coating process could be a big project, and given this project is too close to the end date (September 2018), the reviewer did not believe this can be done by the end of program.

Reviewer 3:

The reviewer commented that this project needs to better define how to identity electrolyte additives for better interface stability. The reviewer said a fundamental study of CEI structure for high-Ni NMCs is important, but the suggestion of spatially resolved energy dispersive X-ray spectroscopy (EDS) will not provide a comprehensive picture to accomplish this goal. The reviewer remarked that developing a low-cost coating process is not an ideal goal for a national laboratory project, particularly because there are already advanced efforts in industry to accomplish this. The reviewer commented that a partnership with a material supplier or company that specializes in ALD coating might be preferred. The reviewer noted that a study of pouch cell configurations to validate results from coin cells is an excellent idea.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

This reviewer expressed that this project supports DOE objectives toward higher energy cathode materials and lower Co contents. The reviewer said that by understanding degradation mechanisms and mitigation strategies, we can guide the design of more robust materials.

Reviewer 2:

The reviewer remarked that high-Ni NMCs offer high energy density and that this is consistent with the overall DOE objective.

Reviewer 3:

The reviewer said the work presented demonstrates a long cycle life, especially the optimized electrolyte. The reviewer noted the ability to achieve 1,000 cycles for 80.6% of cycling with the Li//NMC-76 cell under high voltage (greater than 4.5V) is great.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the project partners applied the sufficient resources to optimize the high-Ni NMCs and achieve the plan in a timely fashion.

Reviewer 2:

The reviewer said that given the scope of the project, that the resources are sufficient.

Reviewer 3:

The reviewer stated the project optimized Ni-rich NMC cathode materials using a controlled co-precipitation method, and improved the cycling stability of NMC-76 cathode materials with optimized electrolyte and additives and/or a surface engineering modification. The reviewer remarked that the project team identified a surface lattice doping effect on the cycling stability of NMC-76 at high charge cut off voltage. The reviewer noted that three out of four milestones were met.

Presentation Number: bat085
Presentation Title: Interfacial Processes—Diagnostics
Principal Investigator: Robert Kostecki (Lawrence Berkeley National Laboratory)

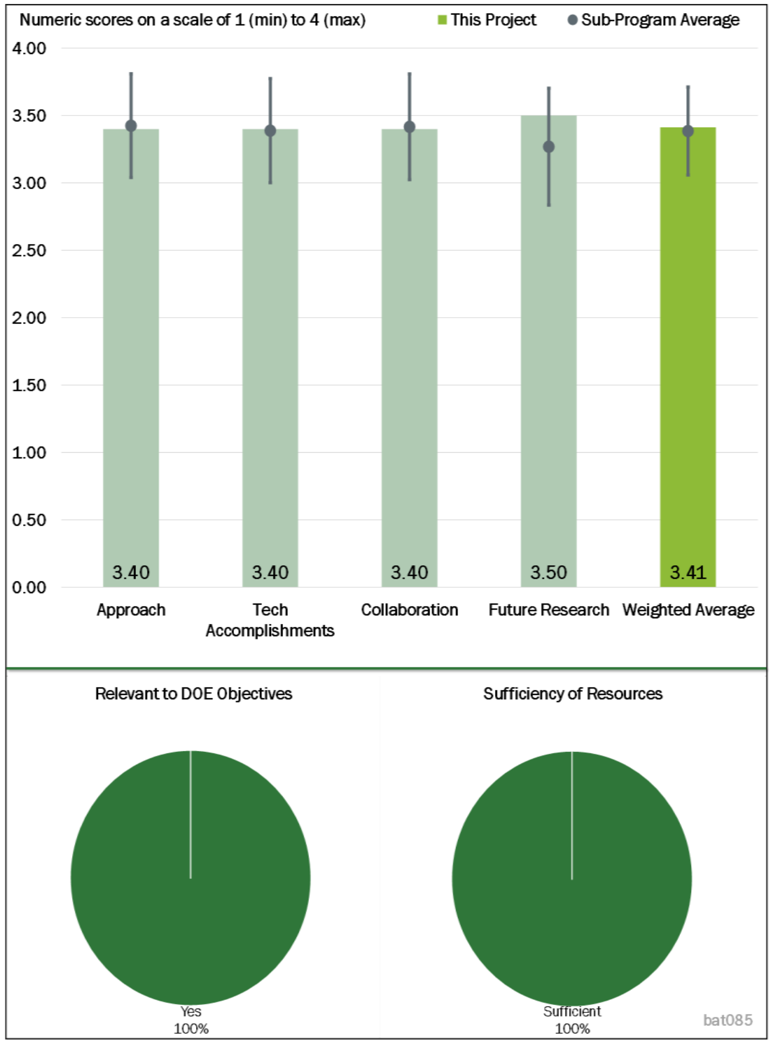

Figure 2-4 - Presentation Number: bat085 Presentation Title: Interfacial Processes—Diagnostics Principal Investigator: Robert Kostecki (Lawrence Berkeley National Laboratory)

Presenter

Robert Kostecki, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the approach taken by the project team is focused, in-depth, and is likely to make progress in identifying the key materials degradations that are occurring and which limit the performance of a Li+ battery. The reviewer noted that using several spectroscopy and microscopy characterization techniques should greatly add to the knowledge base.

Reviewer 2:

The reviewer stated that all the analytical technologies in this program are well-designed to investigate the surface of cathode, which the reviewer finds really important to understanding the mechanism of CEI formation. The reviewer said that utilizing thin-film NMC model electrodes is a great idea to allow more techniques to be applied.

Reviewer 3:

The reviewer commented that the work is well-structured, especially the combination of the different techniques that are examining the same phenomena as a potential way to solve some of the side reaction chemistry that is occurring on the surface of Ni-based oxide active materials.

Reviewer 4:

The reviewer remarked that the objective is to develop new diagnostic techniques (e.g., both in situ and ex situ and far- and near-field optical multifunctional probes) to obtain detailed insight into electrode and electrolyte interfaces at high spatial resolutions. The reviewer noted that the project team has specifically focused on developing thin film, binder-free model cathodes using pulsed laser deposition (PLD), which are cycled in test cells, and analyzed ex situ using sophisticated characterization techniques for understanding the interfacial film-forming reactions involving electrolyte. The reviewer said that this approach allows for understanding the interfacial changes occurring in the cathode materials from the reaction involving electrolyte or the bulk changes, including metal dissolution from the cathode. The reviewer stated that this study will have significance if extended to different high-voltage electrolytes with selected film-forming additives and also high-voltage and high capacity Ni-rich NMC cathode on the cathode with and without coatings. The reviewer said that in principle, this project is well integrated with the other projects under Applied Battery Research for Transportation (ABR) focusing on developing high-voltage electrolytes or Ni-rich cathodes. The reviewer expressed that this project would be even more beneficial if this study provides insights in designing new cathodes (and electrolytes) with improved interfacial stability.

Reviewer 5:

The reviewer said that the thin film NMC (5:3:2) was successfully made by the PLD method. The reviewer noted that the CEI layers were identified by near-field infrared (IR), attenuated total reflection (ATR)-Fourier-transformed infrared spectroscopy (FTIR) and that a mechanistic diagram was presented for the formation of CEI. The reviewer also noted that its thickness is qualitatively related to the increase of interfacial impedance. The reviewer remarked that the experimental evidences for the CEI formation are very helpful in understanding the performance of NMC in Li+ batteries. The reviewer said that it is a pity that other compositions such as 6:2:2 or 8:1:1 were not analyzed, although a reviewer suggested it in 2017.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer expressed that the project team made significant progress in providing insights into how the cathode electrolyte interphase of an NMC cathode effects cell performance.

Reviewer 2:

The reviewer remarked that good progress has been accomplished in unraveling the composition of the CEI on the NMC-532 model electrode, the non-uniform outer layer based on polyethylene glycol, and a uniform and dense inner CEI layer consisting of various Li-electrolyte species (Li alkyl carbonate [$ROCO_2Li$], Li alkoxy species [ROLi], and so on), which can contribute to the impedance towards lithiation and de-lithiation. The reviewer said it is surprising that there is no inorganic component in the inner layer involving the Li salt, as is seen on the anode. The reviewer noted that overall, the progress achieved is quite meaningful and relevant to DOE goals. The reviewer suggested that these studies extend to different electrolytes and cathodes to help with the ongoing efforts in the ABR. For example, the reviewer said it would be easier to assess different electrolytes with NMC-532, compared to cathodes with different compositions. The reviewer said inferences from this study will need to be integrated with findings from similar surface characterization studies under ABR to have a more cohesive and complete picture of the CEI.

Reviewer 3:

The reviewer commented that a lot of good work has been done in the past year. The reviewer would still like to see more data related to Ni-rich materials instead of only NMC-532. The reviewer said because the Umicore is a program partner, it should be relatively easy to conduct some tests by using their Ni-rich materials such as NMC-622 or even NMC-811.

Reviewer 4:

The reviewer said the project team presented results that clearly indicate the relation between surface chemistry and side reactions. The reviewer commented that the information obtained in the project can be helpful in designing new materials and stabilization efforts of existing materials. The reviewer suggested that a more comprehensive study looking at different Ni and Co contents in the cell could decipher side effects of increasing energy content in the material and further provide insight on the surface stabilization of the different materials.

Reviewer 5:

The reviewer commented that the CEI formation was qualitatively observed and its thickness is found to be directly proportional to the increase of impedance. The reviewer remarked that if such a relationship can be quantified by artificially adding the major components of CEI, it would be nicer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the group at LBNL has an excellent collaboration in the national laboratory network and additionally has interactions with universities and two companies. The reviewer noted the input of the two companies mentioned is unclear.

Reviewer 2:

The reviewer said that close collaboration with national laboratories, universities, and industry was evident in the preparation of the thin film sample and the characterization methods development.

Reviewer 3:

The reviewer remarked that collaboration looks strong and sufficient. The reviewer noted that the team did not explicitly explain the role of academic and industry partners.

Reviewer 4:

The reviewer observed significant collaboration with the national laboratories, academia, and industry. The reviewer said it was unclear how each collaborator was contributing to the effort.

Reviewer 5:

The reviewer noted that there are good collaborations with several researchers at LBNL and at other DOE laboratories. The reviewer said it would be have been helpful to list the specific activities in which each of the collaborators is involved. The reviewer expressed that that collaboration with researchers developing new high-voltage electrolytes and high-capacity cathodes would be more beneficial.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the proposed future work includes objectives to investigate state-of-the-art material (i.e., Ni-rich and NMC materials) and the interaction of the active material with inactive components in the electrode. The reviewer commented that these are both topics of high importance and are relevant not only for academia, but also to the Li-cell application itself. The reviewer suggested the project team look at the dynamic interaction of the different components in the composite electrode because this could potentially identify the so-far unknown side reactions, which in turn could be critical for the thermodynamic stability of the system.

Reviewer 2:

The reviewer said the proposed future work is important and logically should be completed in order for a comprehensive understanding of the interfacial properties between electrolyte and NMC cathodes. The reviewer stated that quantification is the key word for the next year of research.

Reviewer 3:

The reviewer noted the proposed future research is good and adequate to cover the next year.

Reviewer 4:

The reviewer remarked the proposed future studies seem to be well organized. The reviewer observed these studies are directed to Ni-rich NMC model systems of different compositions to understand the impedance distribution at each interface, and to quantify the effect of each of the side reactions manifesting in surface films of varying impedance at the cathode electrolyte interface during cycling. The reviewer commented that working closely with the other project teams will undoubtedly be useful to utilize this fundamental understanding in the development of electrolyte and electrodes with stable interfacial properties.

Reviewer 5:

The reviewer said future efforts to work with Advanced Battery Materials Research and industry partners to establish clear connections between diagnostics, theory and modeling, and cell developments are important.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

This reviewer said the project supports the DOE objectives really well. The reviewer noted that understanding the surface layers on the cathode is vital for the development of the high-energy Li+ battery.

Reviewer 2:

The reviewer responded yes, this project does support overall DOE objectives. The reviewer said to enable high-energy materials in Li-ion cells, it is crucial to understand the degradation mechanism occurring on the surface of the material.

Reviewer 3:

The reviewer said this effort is attempting to understand the degradation mechanism of cathode materials for EVs and this clearly supports DOE objectives.

Reviewer 4:

The reviewer observed the project is focused on developing advanced characterization techniques to understand the bulk and interfacial properties of the electrode materials in correlation with their electrochemical behavior. The reviewer also noted the project is integrated with the efforts from other groups in the ABR program. The reviewer commented that performance loss in a Li+ cell during cycling is attributed to the impedance growth, either from the organic layer formed from the reactions with the electrolyte, or the inorganic layer from the surface reconstruction resulting from metal dissolution. The reviewer noted that for designing stable electrodes in conjunction with the high-voltage electrolytes, it is essential to understand these interfacial processes, as the project team has done here. The reviewer remarked that for a widespread use of EVs and PHEVs, batteries with higher energy and lower cost than the current Li-ion batteries are needed. The reviewer said that high-voltage and high-capacity cathodes in conjunction with new high-voltage electrolytes are expected to boost the specific energy and also lower the cost of low-Co formulations, and this is consistent with the goals of the DOE VTO.

Reviewer 5:

The reviewer remarked that interfacial properties play a key role in the stability and safety of Li+ batteries by determining the capacity retention as well as the thermal properties derived from internal resistance.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented the resources are adequate for the scope of the project.

Reviewer 2:

The reviewer believed the team has enough resources to achieve their project goals.

Reviewer 3:
The reviewer commented that the current resources are sufficient to achieve the project targets.

Reviewer 4:
The reviewer stated the resources appear to be adequate for the effort undertaken.

Reviewer 5:
The reviewer remarked that $440,000 a year seems more than enough for 0.3 full-time equivalent and one postdoctoral researcher, but there might be overhead charges or other costs that are not shown in detail. As a foreign reviewer, this was not questioned.

Presentation Number: bat106
Presentation Title: High-Capacity, Multi-Lithium Oxide Cathodes and Oxygen Stability
Principal Investigator: Jagit Nanda (Oak Ridge National Laboratory)

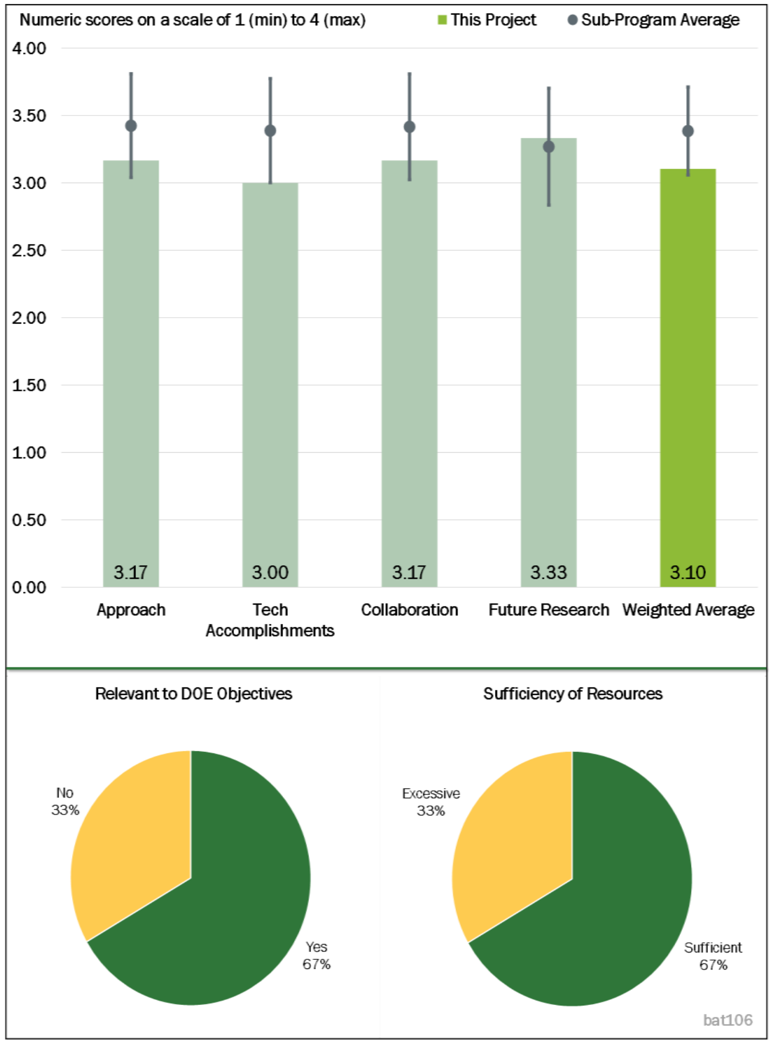

Figure 2-5 - Presentation Number: bat106 Presentation Title: High-Capacity, Multi-Lithium Oxide Cathodes and Oxygen Stability Principal Investigator: Jagit Nanda (Oak Ridge National Laboratory)

Presenter

Jagit Nanda, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said high-Ni-NMCs have been demonstrated as high-energy density cathode materials for next-generation Li+ batteries but the fast capacity fading has been one of the key barriers to commercialize those electrode materials. The reviewer commented the project team applied Li_2MoO_3 as structural unit for stabilizing the NMC material, which is a novel approach.

Reviewer 2:

This reviewer remarked that the project synthesizes an in-depth analysis of Li-excess and multi-Li chemistries for high voltage, high capacity cathodes. The reviewer said the project team made model driven synthetic approaches including solution-based, colloidal solution-integrated network (sol-gel), and solid-state methods. The reviewer noted diagnostic tools include a suite of microscopic, spectroscopic, and analytical techniques.

Reviewer 3:

The reviewer commented the technical aspects of the work appear to be performed reliably and with care. The reviewer cautioned that the relevance of this work is questionable when compared with the stated goals of Battery 500 (i.e., 500 Wh/kg for 1,000 cycles) and the project’s specific objectives. The reviewer remarked the selection of Li_2MoO_3 appears to be a poor choice because of a 1 Li-reversible theoretical energy density (170 mAh/g) that is already lower than current state-of-the-art high-Ni NMCs 622 and 811. Furthermore, the cost of molybdenum (Mo) is not an insignificant factor when compared with Ni and Mn, and assuming a low percentage of Co in the next-generation cathode chemistries. The reviewer said that although oxygen reduction–oxidation may be a viable pathway to achieve higher capacities, Slide 7 indicates that only 1 Li is reversibly intercalated up to 4.8V and oxygen redox does not participate in the reversible chemistry. The reviewer explained that degradation due to oxygen gassing above this potential would be a safety concern and would be very negative for cycle life, but this is not the main drawback of this material. The reviewer noted that findings from the past year confirm several reports dating back at least to 2014 that show Li_2MoO_3 exhibits poor reversibility, but offer little additional insight. The reviewer said that although the true purpose of this project may be to stabilize layered NMC materials, this aspect of the effort seems poorly designed. The reviewer expressed that cycling results involving the Mo-NMC composite cathodes show that there is no apparent benefit to mixing these two cathode compounds. The reviewer said the selection of NMC-111 is unfortunate since NMC-111 is already relatively stable and does not represent the highest capacity state-of-the-art material. The reviewer concluded, it is therefore unsurprising that the project findings show poorer cycle life and capacity behavior for the composite than NMC-111 alone, and that instead using NMC-811 would be desirable to show a benefit from the composite.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that the work presented identified chemical and structural changes that occur in Li_2MoO_3 cathodes during electrochemical cycling. The reviewer commented that the project team unraveled mechanisms of electrochemical activity and degradation of Li_2MoO_3 cathodes using a combination of X-ray and neutron diffraction, Raman spectroscopy, electrochemistry, gas evolution experiments, and TEM. The reviewer said the project team developed synthesis routes to produce composite NMC-based cathodes containing a Li_2MoO_3 structural stabilizing unit.

Reviewer 2:

The reviewer said the project team applied Li_2MoO_3 to stabilize high-Ni NMCs. The reviewer noted that although experimental results showed this approach might have potential, the limited cycle number and the lack of deep structural analysis and mechanism study did not provide solid evidence to support the claims of the project team.

Reviewer 3:

The reviewer stated progress has been made to understand the mechanism of Li_2MoO_3 degradation during cycling, namely the importance of a phase change, which is irreversible. However, there has been no improvement made to the Li_2MoO_3 material that would indicate its ability to meet the Battery 500 500 Wh/kg goal or its cycle life goal. The reviewer commented that as part of a composite, or as a representative of similar compounds, the Li_2MoO_3 results from this year appear to discourage further research into this strategy of improving cathode energy density.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noticed the work has been collaborated among several partners. However, the reviewer believed there is still a gap to understanding the structure and electrochemical mechanism of the new material, but that understanding can be achieved through the collaborative work.

Reviewer 2:

The reviewer said collaboration across the project team is apparent. The reviewer would have expected a greater volume of data from such a diverse team.

Reviewer 3:

The reviewer noted the project team works with PNNL, BNL, and LBNL.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated the proposed future work can provide additional results that were missed in the current report. The reviewer noted that the project team should consider the timeline. The reviewer noted the project will be completed by September 2018 and therefore suggested that the planned items should be prioritized.

Reviewer 2:

The reviewer observed that the work is planned in a logical manner.

Reviewer 3:

The reviewer said that the proposed future work could be interesting from a purely research perspective; however, additional justification would be necessary understand the potential benefits of early TM substitution beyond Mo and Cr. So far, the reviewer has not seen substantial progress from this project toward the high-energy and high-cycle life goals, and the reviewer would be skeptical of a new approach based on the same group(s) of materials.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer noted that Ni-rich NMCs are key cathode materials for high-performance Li+ batteries. The reviewer stated this project investigated a novel approach to stabilize the Ni-rich NMCs.

Reviewer 2:

The reviewer commented that the project objective is to develop high-voltage and high-capacity cathode materials for Li-ion batteries to achieve the Battery 500 goal of 500 Wh/kg for 1,000 cycles. The reviewer noted recent studies have shown that specific rock salt disorder Li excess oxides enable high-voltage stability.

Reviewer 3:

This reviewer remarked that the project could in theory support DOE objectives toward higher cycle life of cathode materials. The reviewer remarked that the way the research was designed and executed makes the output somewhat irrelevant to performance objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that the resources, especially the technical equipment, are sufficient to support the investigation.

Reviewer 2:

The reviewer noted that the project has achieved four out of six milestones and the rest are in progress.

Reviewer 3:

The reviewer stated that compared to highly effective projects with a similar budget, the outcomes of this project suggest that this effort may not be the most efficient use of resources.

Presentation Number: bat164
Presentation Title: Thick, Low-Cost, High-Power Lithium-Ion Electrodes via Aqueous Processing
Principal Investigator: Jianlin Li (Oak Ridge National Laboratory)

Presenter

Jianlin Li, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

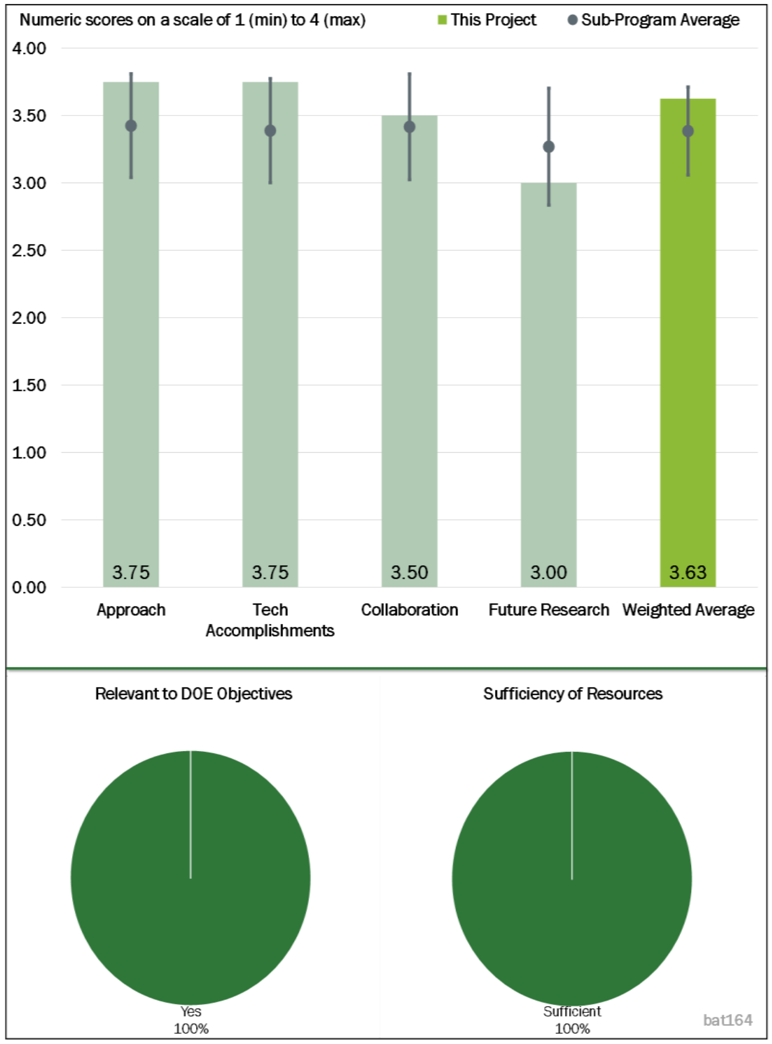

Figure 2-6 - Presentation Number: bat164 Presentation Title: Thick, Low-Cost, High-Power Lithium-Ion Electrodes via Aqueous Processing Principal Investigator: Jianlin Li (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that using a single- and duel-sided caster system, and available aqueous binder systems, enables accelerated materials development.

Reviewer 2:

The reviewer remarked that the technical approach addressed the energy and power density and battery production cost by developing a thick electrode via aqueous processing.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said the technical approach sounds productive. The reviewer noted the progress is aligned with the plan.

Reviewer 2:

The reviewer said the team has demonstrated a successful fabrication of multilayer structure which is functional for application.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented a strong team has been put together, and noted the project team consists of academia and industry partners collaborating to attack the technical barriers.

Reviewer 2:

The reviewer pointed out that the project team has interacted and partnered with multiple national laboratories and industrial partners.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted that the project team has an acceptable future work plan, and suggested the work plan could be improved with the addition of a specific set of metrics for the team to achieve.

Reviewer 2:

The reviewer commented that battery energy density appears to be more important than energy density for vehicle applications due to limited packing space. The reviewer suggested that the project team show the energy density of the cell with the new manufacturing processing compared to that of the base cell. The reviewer expressed that if possible, the cell level cost reduction with the new manufacturing processing should be quantized.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer remarked the project supports the goals for battery cost reduction and specific energy density increase.

Reviewer 2:

The reviewer noted that energy storage is of greater importance in the overall landscape of energy generation, use, and so on.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that the resources appear to be sufficient for the proposed efforts.

Reviewer 2:

The reviewer said the team has access to equipment, materials, and a technical team to sufficiently perform the described work plan.

Presentation Number: bat168
Presentation Title: Process Development and Scale-Up of Critical Battery Materials—Continuous Flow-Produced Materials
Principal Investigator: Krzysztof Pupek (Argonne National Laboratory)

Presenter

Krzysztof Pupek, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

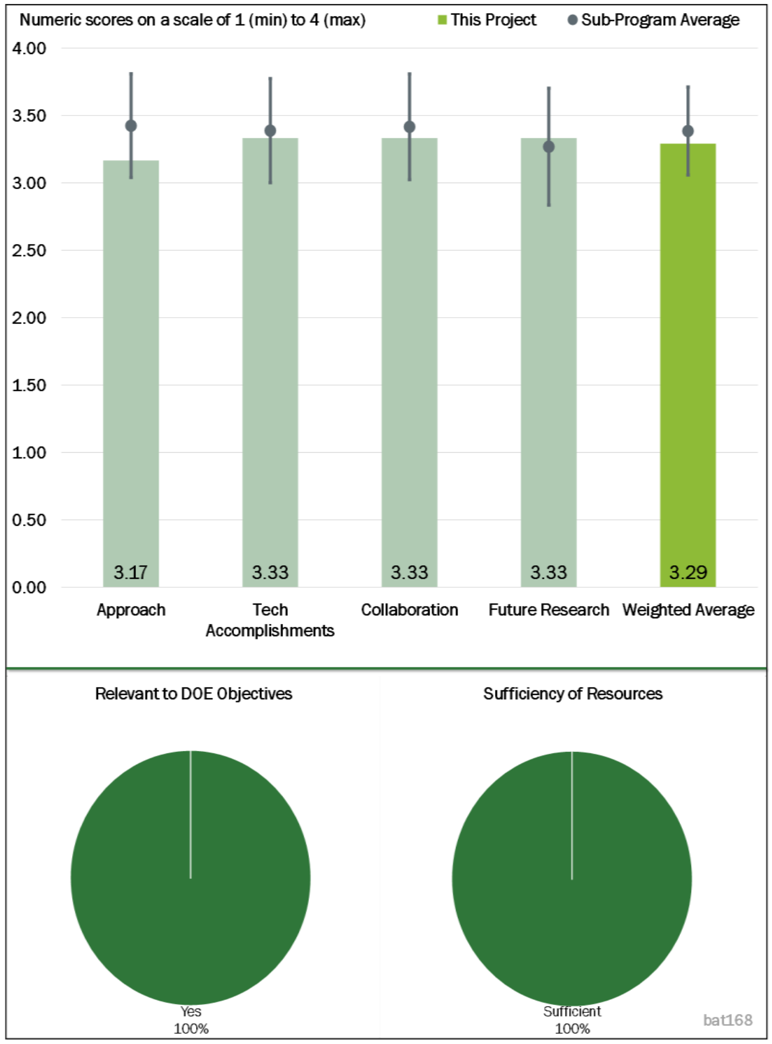

Figure 2-7 - Presentation Number: bat168 Presentation Title: Process Development and Scale-Up of Critical Battery Materials—Continuous Flow-Produced Materials Principal Investigator: Krzysztof Pupek (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said the project team collected information about new materials and evaluated new, emerging manufacturing technologies to design the continuous flow reactor-based reaction to realize scale-up synthesis. The reviewer said that this is an excellent and effective approach to perform the work.

Reviewer 2:

The reviewer remarked that having a reliable source of high interest materials for development and characterization is an important aspect of material evaluation in battery systems. The reviewer said this work attempts to use certain "high volume" lab techniques to determine if some materials can be produced in a repeatable, reliable manner. The reviewer said that it is presumed that if materials are amenable to this approach at this scale, then materials may also be amenable to continuous processing at a commercial scale, although this is not a given.

Reviewer 3:

The reviewer remarked the project approach is fairly solid, with a focus on scale-up from "beaker to jug." The reviewer acknowledged the emphasis on continuous reactors and green chemistry is appropriate to start bridging bench scale with industrial scale. The reviewer elaborated on several doubts about this approach. First, the reviewer noted the scale being attempted, which the presentation stated is on the order of 500 g or possibly up to the kilogram scale. The reviewer said while this constitutes a scale-up for sampling, it does not begin to approach a pilot scale that would be needed for truly bridging industrial production. Second, the presentation repeatedly mentioned the importance of cost in scale-up, yet this aspect of the project has been neglected. The reviewer said cost estimations for both the raw materials and processes for each compound should be considered essential to this work and perhaps could help in the downselection of compounds to be synthesized. Third, the decision-making process for which compounds to produce is selected is fairly opaque. The reviewer noted that there was some discussion during the presentation about a program manager review at the start of each scale-up, but what goes into this review is unknown. The reviewer would like more information about if these compounds are exclusively developed at national laboratories or requested by an industry partner, or if there is a known barrier to scale-up that this effort can address. Fourth, there is not enough feedback from the partners that sample these materials. The reviewer said in order to gauge the value of this effort we would have to know whether the materials being supplied are of industrial use and whether they enable a performance benefit. The reviewer noted part of the material sampling process should involve some requirement that evaluation data be shared. Fifth, in order to understand the benefit of the scale-up effort, more details about the quality of the material being produced and whether this is better or worse than the bench scale processes are needed. The reviewer said impurity concentrations and reactant utilization are standard metrics for success in such an effort.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer pointed out that the key project accomplishments are developing a cost-effective process to synthesize the advanced battery materials. The reviewer remarked that the team has successfully developed several novel electrolyte additives in the targeted timeline.

Reviewer 2:

The reviewer stated that some of the materials were amenable to this approach and that some were not. The reviewer said that this is perhaps not unexpected. The reviewer commented that it would have been helpful to provide an update on how much material of each type was produced and how many samples have been delivered for evaluation.

Reviewer 3:

The reviewer remarked that the synthetic accomplishments of this project are admirable. The reviewer commented that several Si containing solvents, fluorinated additives, and Li salts have been produced in continuous processes at scales of hundreds of grams and sampled to partners. The reviewer said that although the approach to solid-state electrolytes (SSEs) was unsuccessful, this finding is not much of a surprise. The reviewer reiterated that, as stated previously, the effort to scale-up itself should be justified by the end result of the partners who sample the material and therefore, more data on how these materials are used is necessary going forward. The reviewer said that the cycling data presented for Si containing carbonate electrolytes is an insufficient justification, because the value of this material is as a flame retardant. As the PIs are no doubt aware, reviewers also require more information about the particular test conditions for each electrochemical cell because the compatibility of solvents, additives, and salts depend on the electrode materials used.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that this project has linked with many research institutes and companies, and has been intensively collaborated.

Reviewer 2:

The reviewer commented that collaboration between Materials Engineering Research Facility (MERF) and research scientists within ANL appears to be effective. The reviewer noted that it will be important, however, to strengthen the collaborations between MERF and outside partners who sample materials in order to obtain feedback and results that guide future scale-up development and research.

Reviewer 3:

The reviewer stated that the collaboration appears to be sufficient. It is critical that the choice of materials for development as well as the ability to distribute it to a wide audience be highly collaborative. Per the reviewer, the effectiveness of this project depends entirely on serving the community's needs.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the main target of this project is continuously developing a scale-up synthesis approach. The reviewer reported that optimization and evaluation of new materials has also been planned.

Reviewer 2:

The reviewer indicated that the activities for the next FY are largely a continuation of existing efforts and new materials will be identified and scaled. However, the reviewer recommended that the number of materials to be scaled is reduced, to allow complementary efforts including greater emphasis on cost analysis, innovation in scale-up processes to address industry shortcomings, and verify the usefulness of the materials being produced.

Reviewer 3:

The reviewer had no special comments on future directions.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer stated that the project is a key missing link between inventing new advanced battery materials, performing a market evaluation of these materials, and manufacturing at high-volume, reducing the risk associated with the commercialization of new battery materials.

Reviewer 2:

The reviewer commented that the materials research on promising materials candidates cannot occur without a consistent, viable source of the target material.

Reviewer 3:

The reviewer stated that this effort supports DOE objectives to transfer R&D materials into industry. The reviewer said that sampling larger scales of materials is important, but it must be complemented by better engagement and feedback from industry partners.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked that the resources appear sufficient, but additional resources may help to expand the scope and synergistic activates (as previously described) that will make this effort even more valuable.

Reviewer 2:

The reviewer stated that the resources, including both collaborative support and in-house capability, are sufficient to perform the research activities for this project.

Reviewer 3:

The reviewer had no comments on resources.

Presentation Number: bat183
Presentation Title: In Situ Solvo-Thermal Synthesis of Novel High-Capacity Cathodes
Principal Investigator: Feng Wang (Brookhaven National Laboratory)

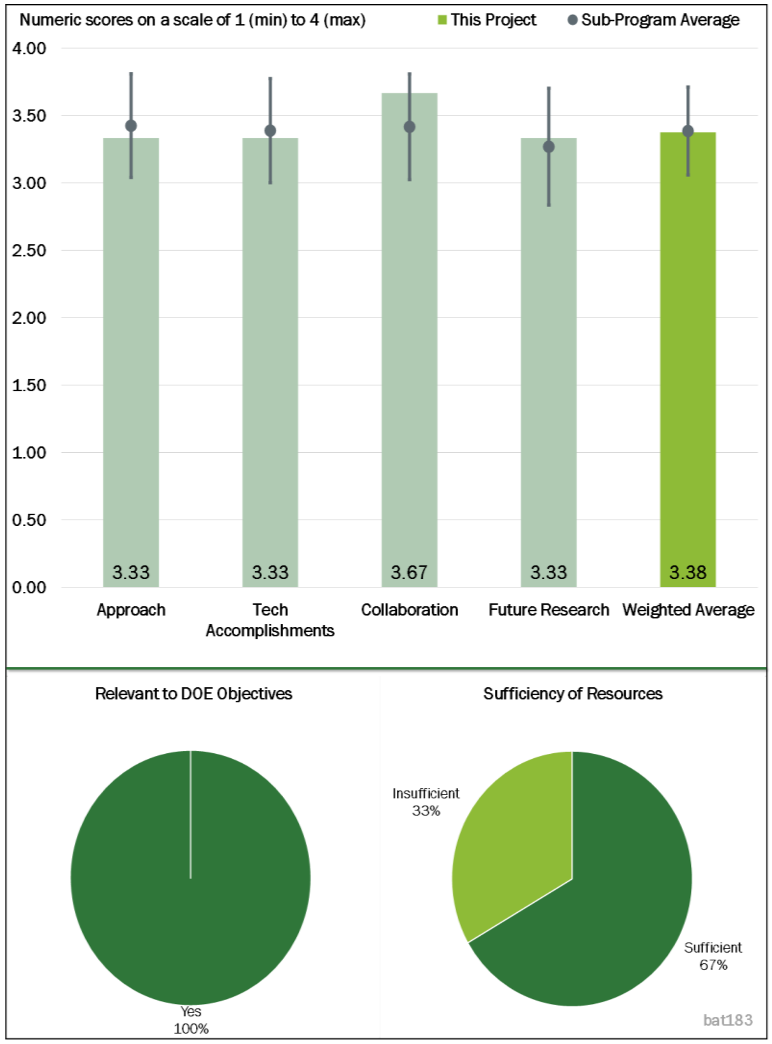

Figure 2-8 - Presentation Number: bat183 Presentation Title: In Situ Solvo-Thermal Synthesis of Novel High-Capacity Cathodes Principal Investigator: Feng Wang (Brookhaven National Laboratory)

Presenter

Feng Wang, Brookhaven National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that this project is well designed and focused on understanding the synthesis parameters that influence the crystal structure of high Ni NMCs. The reviewer stated that the techniques used are complementary and varied. The reviewer pointed out that particular emphasis is placed on in situ X-ray characterization, which is excellent. The reviewer noted that because the focus of this work fundamentally uses X-ray techniques, there is a concern that the measurements are primarily of bulk crystal evolution rather than surface states, despite the use of spatially resolved spectro-imaging. The reviewer said that if future work is to focus on gradient cathodes or potential coated cathode materials, which is an area of practical concern for NMC-811, that some study of surface states would be complementary.

Reviewer 2:

The reviewer said that electrochemical performance of electrodes is highly dependent on the structural information (e.g., phase, purity, morphology, and so on) of electrode materials. The reviewer commented that this project developed the in-situ techniques to track the structural evolution of electrode materials, which will be critical to optimize the synthesis process.

Reviewer 3:

The reviewer remarked that in situ techniques are developed for structure-tracking aided synthetic design of electrode materials with desired phases and properties. However, there is a big technical challenge. The reviewer elaborated that there is no theory or design principles on synthesizing materials of desired structure and properties, and therefore the project team knows what is wanted but it is unknown how to make what is wanted.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the accomplishments of this project provide great insights to understand the structural evolution of electrode materials from local and long range of transition metals (TMs) in NMC materials. The reviewer noted that this insightful understanding will guide the future investigation, to optimize the synthesis of high-energy density electrode materials.

Reviewer 2:

The reviewer said significant progress has been made to study the role of temperature and time on crystal structure evolution and oxidation states of TMs in NMCs. The reviewer said that the results are clear and that it will be useful in the development of high-capacity, long cycle life cathode materials. The reviewer recommended that in future work, the project would benefit from a comparison across different compositions of NMCs including NMC-622 and NMC-811, which may be more commercially relevant that NMC-71515. The reviewer noted that study of solid-state synthesis from hydroxide precursors makes sense, but that additional information on materials synthesized from carbonates or in solvothermal processes (as the project title suggests) would be equally valuable.

Reviewer 3:

The reviewer remarked that this project developed in situ techniques, allowing for multimodal characterization of solid-state synthesis under controlled atmosphere. However, designing and synthesizing specific cathode materials have proven difficult.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted the team of collaborators on this project is very strong.

Reviewer 2:

The reviewer remarked that this project is collaborated by more than 10 national laboratories and national and international universities.

Reviewer 3:

They reviewer stated that the project team works with LBNL, ORNL, ANL, Stony Brook University, Xiamen University, Alfred University, and Seoul National University.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said strong suggestions about future and ongoing work have been made to support this effort. The reviewer noted that a focus on cooling rate and Mn/Co substitution on cation ordering is a very important area of study. The reviewer said, however, more definition needs to be given to the spatially resolved techniques that could be sensitive to structural ordering. The reviewer would like to know what the recommendation is for spatial techniques and if this would this contribute to the understanding of order at or near particle surfaces.

Reviewer 2:

The reviewer believed the proposal research topics are excellent, which will focus on Ni-rich NMCs but at the same expand this technology to other batteries. The reviewer suggested linking the prepared material with the electrochemical properties, because this will close the loop of synthesis, mechanism understanding, and electrochemical properties.

Reviewer 3:

The reviewer said that the planned work includes applying the established approaches and techniques to synthesis of high-Ni layered oxide cathodes and other type of battery materials. However, given it is close to the project end date of October 2018, this could be a challenge.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer remarked that this project is very important for meeting DOE objectives toward developing higher capacity and lower Co cathode materials.

Reviewer 2:

The reviewer said the DOE overall target is to develop low-cost cathode materials with high energy density and electrochemical properties. The reviewer commented that the project focus is investigating the structural evolution of Ni-rich NMCs during synthesis, which is consistent with DOE’s goals.

Reviewer 3:

The reviewer stated that the project is to develop low-cost cathode materials with high energy density and electrochemical properties (e.g., cycle life, power density, safety, and so on) that are consistent with the U.S. Advanced Battery Consortium’s (USABC) goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources are sufficient for this project; however, additional resources could benefit collaborative efforts and expand the scope of this very important project.

Reviewer 2:

The reviewer commented that this project has enough resources, including staff and equipment, from national laboratories and universities to achieve the goals.

Reviewer 3:

The reviewer commented that this project has achieved three out of five milestones and that one milestone has been delayed and one is pending.

Presentation Number: bat220
Presentation Title: Addressing Heterogeneity in Electrode Fabrication Processes
Principal Investigator: Dean Wheeler (Brigham Young University)

Presenter
Brian Mazzeo, Brigham Young University

Reviewer Sample Size
A total of three reviewers evaluated this project.

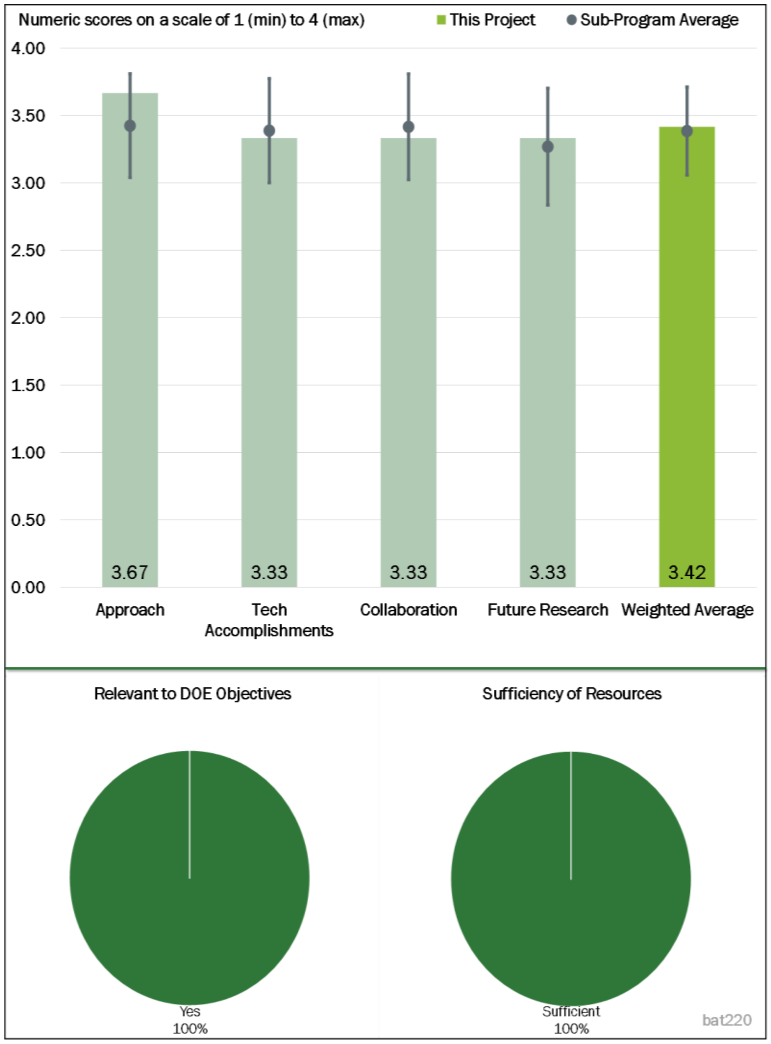

Figure 2-9 - Presentation Number: bat220 Presentation Title: Addressing Heterogeneity in Electrode Fabrication Processes Principal Investigator: Dean Wheeler (Brigham Young University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer commented that the project team continues to do an outstanding job of developing a new technique allowing a better understanding of the effects of electrode heterogeneity of cell performance. The reviewer expressed that this effort is addressing a critical issue to the development of a long cycle-life, affordable battery.

Reviewer 2:
The reviewer remarked that the approach is outstanding and really shows a great benefit for industry.

Reviewer 3:
The reviewer noted that the device developed so far, for conductivity measurement, can reveal the situation of the electrode made from role to role. The reviewer was unable to tell how this will be applied to the fast-charged electrodes, especially after its cycling.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer expressed that the project team continues to make excellent progress. The reviewer commented that improvements were made to the micro-line probe. The reviewer explained that focused ion beam scanning electron microscopy (SEM) was used to analyze commercial electrodes and a rolling probe was developed to make conductivity measurements over large area electrodes. The reviewer said that the project team is meeting their milestones and are making significant contributions to the field.

Reviewer 2:
The reviewer remarked that a lot of great technical accomplishments have been shown in the project. The reviewer commented that the project team made a big effort to enable its technologies for industry partners and even started to sell its first commercial product. The reviewer was confused about the meaning of future technical accomplishments and was unsure if some work was ahead of schedule.

Reviewer 3:
The reviewer noted that some results were obtained for conductivity, as well as Young's modulus measurement. The reviewer remarked that there is still a significant difference between model prediction and experimental measurement for the physical properties of the porous structure. The reviewer commented that the relationship between conductivity, Young's modulus, and the fast-charging properties has not been identified.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer remarked excellent contributions with industry (e.g., Hydro-*Québec*, Bosch, K2, and LG Chem) and the national laboratories exist.

Reviewer 2:
The reviewer stated that clearly the project team has a large collaborative network within its university, and beyond, including national laboratories and industries.

Reviewer 3:
The reviewer remarked that some improvements can be made for industrial collaborations. The reviewer noticed that all the materials tested in were from ANL and that more commercially relevant materials should be considered for future testing.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that the proposed future activities are well thought-out. The reviewer said the proposed future research is logical and should lead to a technique that industry can use.

Reviewer 2:
The reviewer noted that the proposed future research is adequate for this project. The reviewer said that there are a lot of challenges that need to be overcome to enable this really cool technique. The reviewer also remarked that the speed for identification of the quality of different electrode materials was not clearly mentioned.

Reviewer 3:
The reviewer commented that there are six milestones to achieve in the remaining year. The reviewer said that besides the durability and reliability test of the conductivity measuring device, the remaining part of the project deals with the particle packing properties derived from drying and calendering. The reviewer commented that the project team wishes to do this using simulation rather than doing experiments. In fact, the drying conditions and drying technologies would significantly affect the porous structure of the electrode film made. The reviewer said the calendering conditions (nip thickness and pressure) would change the density significantly. The reviewer said that the project team should carefully consult the related literature in order to have applicable simulation results.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented that this project is definitely supporting DOE VTO objectives. The reviewer noted that the effort may lead to lowering cell cost. The reviewer said that battery manufacturers will have a better way to quality control their electrodes.

Reviewer 2:
The reviewer remarked that the project shows strong support for DOE objectives, which can definitely save the Li-ion industry a lot of costs.

Reviewer 3:
The reviewer remarked that the microstructure of the electrode film will have a significant effect on its electrical conductivity, its rate performance, or its charging rate. The reviewer remarked that fast charging is important for passenger cars. The reviewer stated that the project does not show any effort in overcoming the cost or capacity barriers.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer suggested that DOE consider increasing the funding for this project. The reviewer hopes that this technique can be quickly applied by Li+ cell manufacture companies, which may demonstrate a big effect in the near future.

Reviewer 2:
The reviewer stated that the resources appear to be appropriate and that significant progress is being made.

Reviewer 3:
The reviewer remarked that no financial report was given and therefore assumed the project funding is sufficient.

Presentation Number: bat230
Presentation Title: Nanostructed Design of Sulfur Cathode for High Energy Lithium-Sulfur Batteries
Principal Investigator: Yi Cui (Stanford University)

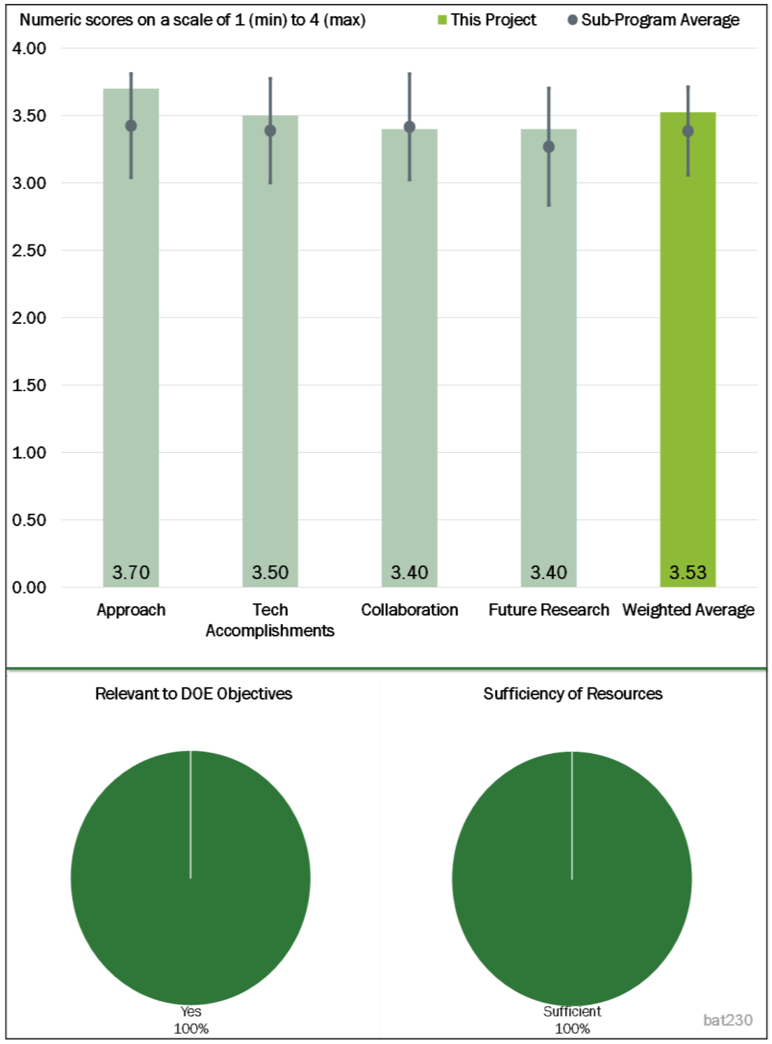

Figure 2-10 - Presentation Number: bat230 Presentation Title: Nanostructed Design of Sulfur Cathode for High Energy Lithium-Sulfur Batteries Principal Investigator: Yi Cui (Stanford University)

Presenter

Yi Cui, Stanford University

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that based on the extensive and outstanding background research on lithium-sulfur (Li-S) from the project team, the present project made a number of new advances in this field that are of world-class quality. The findings of proper catalysts in overcoming the overpotential for Li_2S oxidation, quantifying various adsorbents for Li_2S, as well as the unique inorganic binder for Li-S cathode preparation, all represents significant achievement in their own regards. The reviewer commented that the results have been published in top ranked journals, and noted that the PI has been invited to give seminars worldwide.

Reviewer 2:

The reviewer remarked that the project team has done an excellent job in studying nanostructured design of the sulfur cathode for high-energy Li-S batteries with high capacity and stability. The reviewer commented that the project team quantitatively measured the polysulfide adsorption amount of candidate materials, uncovered different adsorption mechanisms, and identified possible adsorption species. The reviewer said that the study on multi-functional sulfur cathode binder capable of controlling of the polysulfide shuttling and facilitating Li^+ transport is of great interest. The reviewer praised the project team for making remarkable progresses in addressing the technical barriers.

Reviewer 3:

The reviewer praised the project team for an excellent approach. The reviewer commented that the project team can always find a right direction to work in and is very productive.

Reviewer 4:

The reviewer remarked that the engineering advanced nanostructured sulfur cathodes, characterization, and cell testing approach is comprehensive, focused, rigorous, and feasible. The reviewer noted that this past year the project team focused on combining theoretical calculations and experiments to identify the key parameters in determining the energy barrier for Li_2S oxidation and polysulfide. The reviewer commented that this work is definitely addressing the key technical barriers of the Li-S system.

Reviewer 5:

The reviewer summarized that objective is to develop high capacity and long-life sulfur cathode using nanostructured sulfur cathodes with: various mesoporous C hosts with and conductive polymer coating; yolk-shell with titanium dioxide-sulfur (TiO_2-S) nanoparticles; transition metal sulfide coatings; and new inorganic binders. The reviewer stated that the approach is multifaceted with several material modifications and that some of them look promising, but overall it appears to be difficult to have a quantitative comparison of the benefits from one approach to another. The reviewer remarked that the path towards maturation of one or two of these approaches is required for this development to go forward and is not detailed here. The reviewer said there was no discussion on how the Li anode will be modified to be dendrite-free and tolerant to polysulfide poisoning during extended cycling. The reviewer commented that cell designs with dense cathodes and limited electrolyte will need to be employed to demonstrate the benefits of nanostructured sulfur cathodes. The reviewer noted that the project is well integrated with the projects under Battery 500, especially with PNNL where a long-life Li anode is being developed. The reviewer noted that integrating the sulfur cathode with this anode may be beneficial later on, provided the electrolytes are compatible.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer expressed that the project team has made excellent progress this year. The reviewer commented that significant advancements were made with respect to reducing the dissolution of Li polysulfides. The reviewer noted a series of metal sulfides were investigated as polar hosts and the key parameters to polysulfide absorption were identified.

Reviewer 2:

The reviewer remarked that a number of new achievements have been obtained in addition to the vast and excellent previous results reported from the project team. The reviewer stated they are of first-class quality.

Reviewer 3:

The reviewer commented that the project team has demonstrated several technical accomplishments and progresses towards the overall project. The reviewer said the project is in good shape in terms of milestones.

Reviewer 4:

The reviewer commented on the impressive progress that has been accomplished in developing long-life sulfur cathodes with various modifications, including nanostructured C hosts confining sulfur, conducting polymer coatings, yolk-shell nanomaterial with TiO_2 over sulfur, coating sulfur with various metal sulfides, and finally using a new inorganic binder. The reviewer remarked that detailed studies have been made to understand the role of various metal sulfides (MS_2) in trapping polysulfides within the cathode. The reviewer noted that impressive publications have resulted from these studies. The reviewer summarized that overall, the progress achieved here is quite meaningful and relevant to the DOE goals. The reviewer also commented that it appears that some of these studies were made prior to the Battery 500 projects. Details on the electrode and cell design, such as sulfur loadings and electrolyte content, are missing in these charts. The reviewer remarked that this multi-faced approach, though justified in the academic environment (e.g., as topics for doctoral studies), does not look as cohesive here and some of the aspects may not be amenable to scale-up. The reviewer suggested to prioritize these approaches and integrate them, possibly for synergistic effects in larger cells, and possibly collaborating with industrial partners, because these types of studies will serve the Battery 500 project objectives better.

Reviewer 5:

The reviewer acknowledged that the project team performed enormous work. However, the project team should focus on the most recent progress, instead of listing all the accomplishments during this program. The reviewer hoped the project team can do a better job and give enough guidance for each accomplishment.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer expressed that collaboration looks really strong for this project. The reviewer noted that because the Li-S battery needs more focus on the fundamental understanding and development, a strong connection with academia is a must.

Reviewer 2:

The reviewer remarked that the project team has been collaborating with national laboratories and other universities. The reviewer noted that the collaboration is very productive.

Reviewer 3:

The reviewer stated that the project team has extended its collaboration network to include colleagues from Stanford University, a governmental laboratory, an industrial company, and two Chinese universities. In his new project’s involvement with Consortium 500, he is collaborating with even more top researchers in the United States.

Reviewer 4:

The reviewer remarked that in the United States the team is collaborating with one company, Amprius, and other Battery Material Research (BMR) Program project teams.

Reviewer 5:

The reviewer remarked that there are good collaborations with several researchers within the Battery 500 project. The reviewer stated that Amprius was listed as the collaborator, but it was not clear what the collaboration is. The reviewer stated that it is probably appropriate to collaborate with the other DOE national laboratories outside the Battery 500 project or with an industrial partner (which may be Amprius) to make large format-pouch cells to demonstrate the benefits with these materials.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that rate capability, higher loading, and shuttle effect are still big challenges to the Li-S battery. The reviewer commented that the project team noticed those problems and has made good progress in the past to solve those problems. The reviewer concluded that the proposed future work seems logical and necessary.

Reviewer 2:

The reviewer commented that the proposed future work is well-planned. The reviewer said the project team will focus on several key tasks such as the interaction between sulfur species and multifunctional binders. The reviewer remarked that the proposed road map is very thoughtful and makes sense.

Reviewer 3:

The reviewer stated that the proposed future work is all on challenging topics facing the Li-S community. The reviewer expressed that achievement from even part of the listed tasks would make significant impact to Li-S R&D.

Reviewer 4:

The reviewer stated that future efforts are directed toward may of the issues confronting the development of a Li-S battery. The reviewer noted that although the details were not specifically identified on the slides, that the presenter was able to provide detailed plans upon questioning.

Reviewer 5:

The reviewer said that there are good collaborations with several researchers within the Battery 500 project. Amprius is listed as the collaborator, but what the collaboration would be was unclear. The reviewer opined that it is probably appropriate to collaborate with the other DOE national laboratories outside the Battery 500 project or an industrial partner (maybe Amprius) to make large-format pouch cells to demonstrate the benefits with these materials.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer expressed that for a widespread use of EVs and PHEVs, batteries with higher energy and lower cost than the current Li-ion batteries are needed, and Li-S system is expected to fulfill these needs because of the high capacity and low cost of sulfur. The reviewer stated that new high-capacity and long-life sulfur cathode materials are desired to meet DOE goals, which the project has been addressing.

Reviewer 2:

The reviewer remarked that developing stable and high capacity sulfur cathodes is critical for high energy Li-S batteries to power EVs, and is highly relevant to the VTO program goal. The reviewer commented that the approach using nano-architecture is innovative.

Reviewer 3:

The reviewer said that the project is highly relevant and is in direct support of VTO goals.

Reviewer 4:

The reviewer remarked that improvement of the high-energy and low-cost sulfur cathode material is critical for the development of the next generation of Li batteries. The reviewer noted that this project feeds this purpose really well.

Reviewer 5:

The reviewer commented that the Li-S is known for its low price and high energy capacity. The reviewer said that safe and stable Li-S is believed to be the next generation of power supply for EV or power tools.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

From the outstanding research outputs observed by this reviewer, the project team should have put in more resources than the allocated funding for this research topic. The reviewer elaborated that because there was no complaint from the project team about short funding that it is assumed to be sufficient.

Reviewer 2:

The reviewer stated that the project team has fully used the resources at Stanford University including the Stanford Linear Accelerator Center (SLAC) for in situ X-ray and with Amprius Inc. through collaboration.

Reviewer 3:

The reviewer said that the resources are adequate for the scope of the project.

Reviewer 4:

The reviewer believes the resources are sufficient for the project.

Reviewer 5:

The reviewer stated that the project team has the resources to complete the investigation in a timely manner.

Presentation Number: bat232
Presentation Title: High Energy Density Electrodes via Modifications to the Inactive Components and Processing Conditions
Principal Investigator: Vincent Battaglia (Lawrence Berkeley National Laboratory)

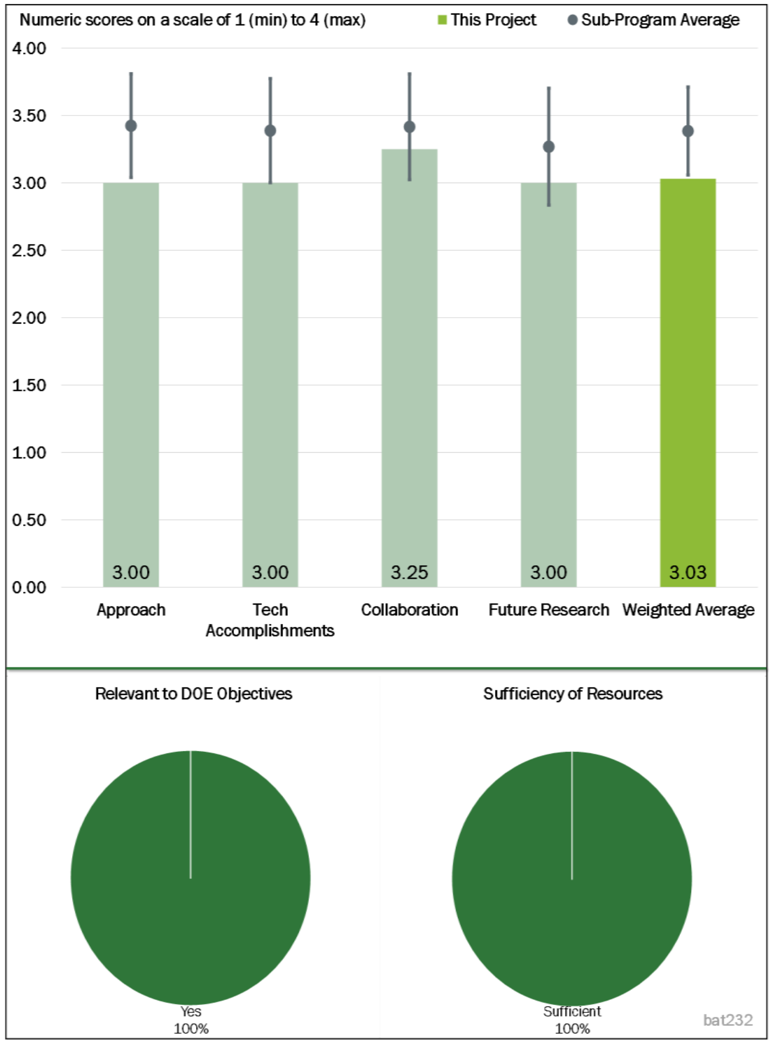

Figure 2-11 - Presentation Number: bat232 Presentation Title: High Energy Density Electrodes via Modifications to the Inactive Components and Processing Conditions Principal Investigator: Vincent Battaglia (Lawrence Berkeley National Laboratory)

Presenter
Vincent Battaglia, Lawrence Berkeley National Laboratory

Reviewer Sample Size
A total of two reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer said the project team addressed the energy and power density and battery production cost.

Reviewer 2:
The reviewer stated that the approaches and evaluations of work used are standard to the industry, which is acceptable, but does not introduce anything novel to justify the project funding.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer remarked that the technical progress has been achieved as planned.

Reviewer 2:
The reviewer commented that the project team restricts itself to materials sets which preclude fabrication of thicker materials. The reviewer said the thick-film electronics industry has demonstrated capability to fabricate quality substrates of many compositions, at thicknesses of well over 1200 micrometers in thickness. The reviewer asserted that binder-solvent systems that do not “mud-crack,” yet yield thick, high-density films need to be considered.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer remarked that the collaboration across the project team members appears excellent.

Reviewer 2:
The reviewer commented that the project team has reached out to industrial partners. However, it appears the project team has not taken advantage of efforts and accomplishments at other national laboratories.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the proposed work is expected.

Reviewer 2:
The reviewer was hoping to see more close talks between the project team and the battery industry for the transitioning of the technical achievement to industry, even though it was not the major focus of the project.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer remarked that the project supports the goals for battery cost reduction and specific energy density increase.

Reviewer 2:
The reviewer stated that systems with enhanced energy storage performance are desirable.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the resources appear to be sufficient for the proposed efforts.

Reviewer 2:
The reviewer said the project team should take advantage of equipment and technical expertise at other national laboratories and academic institutions.

Presentation Number: bat235
Presentation Title: Characterization Studies of High-Capacity Composite Electrode Structures
Principal Investigator: Jason Croy (Argonne National Laboratory)

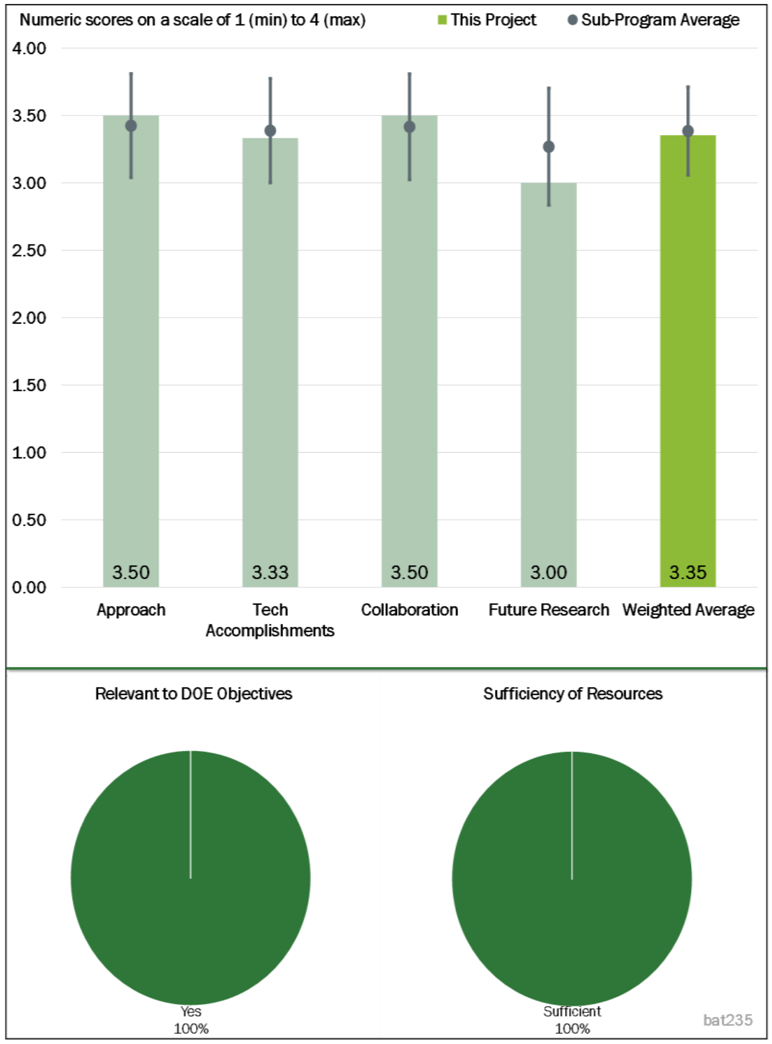

Figure 2-12 - Presentation Number: bat235 Presentation Title: Characterization Studies of High-Capacity Composite Electrode Structures Principal Investigator: Jason Croy (Argonne National Laboratory)

Presenter

Jason Croy, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the project approach is innovative and novel, involving the integration of spinel nano-domains directly into a high-energy LL cathode material to provide stability. The reviewer expressed that achieving reasonable dispersion of the spinel component, however, presents a synthetic challenge. The reviewer noted that cation substitution is a reasonable approach with low-temperature-lithium cobalt oxide and the decision to focus on Al substitution to achieve cycle stability was informed by prior work. Moving to a modified sol-gel approach to integrate the spinel as a composite is somewhat effective. The reviewer suggested that perhaps the most valuable effort is the thorough characterizing different compositions of LLS composites to provide a guideline for the future design of integrated spinel in LLS.

Reviewer 2:

The reviewer remarked that the project combined several resources to promise an unparalleled look into the structural, electrochemical, and chemical mechanisms in complex electrode/electrolyte systems. The reviewer commented that the work presented focused on composite LL, LLS, and endmember components in order to inform and accelerate the design of high-energy, composite cathode materials.

Reviewer 3:

The reviewer noticed that a wide array of characterization techniques including X-ray and neutron diffraction, XAS, nuclear magnetic resonance (NMR), and TEM have been applied to understand the structural information of the novel LLS high energy density cathode materials.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the technical accomplishments and progress are excellent. The reviewer stated the project proceeds in a logical manner and many characterization techniques have been used to fully understanding the structural information of the cathode materials with various doping/synthesis approaches. The reviewer commented that all of the achievements are critical to realize the overall goals.

Reviewer 2:

The reviewer remarked that the project has made good progress toward developing strategies to improve the performance of LL cathodes. Techniques involving cation substitution and composite synthesis of LLS cathodes may be effective to achieve higher energy densities (the former likely being more reliable), although progress has been slowed by synthetic challenges. The reviewer remarked that results from the composite synthesis of LLS cathodes strategy of preparing composites by a modified sol-gel method is not convincing from an electrochemical performance perspective or the proposition of synthetic scale-up, but was obviously a risk mitigation strategy. Despite this, the thorough characterization of different composite compositions is a valuable contribution toward LLS design. Nevertheless, more effort should be placed on performance evaluation in battery cell environments, which demonstrate high energy. The reviewer remarked that using computational simulation to provide an explanation for structural damage during cycling, though interesting, could be better supported by experimental efforts.

Reviewer 3:

The reviewer remarked that the project demonstrates Al-substitution is the most effective in enhancing the cycle stability. The reviewer said synergistic performance improvement by LT Al surface treatment and electrolyte additives is confirmed in LLS//Gr full cells.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said collaboration across the technical team seems to be very effective.

Reviewer 2:

The reviewer commented that this work is a collaboration between many national laboratories (ANL and PNNL), and universities (Northwestern University, etc.).

Reviewer 3:

The reviewer noted that the project team works with different teams at ANL, the Pohang Accelerator Laboratory in Korea, PNNL, and Northwestern University.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted that the project has ended.

Reviewer 2:

The reviewer noted that the project has ended.

Reviewer 3:

The reviewer remarked that the future project plan appears reasonable but that it is largely a continuation of the current strategy, which has been slowed by synthetic challenges. The reviewer suggested that perhaps a different methodology, making use of additional collaborators with experience in particle growth processes, could be utilized for faster development.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer commented that the LLS composite cathodes with suitable surface coatings are promising to provide stable structures, with high capacities at high rates and are being addressed in the project. The reviewer remarked that the project is highly relevant to the DOE goals.

Reviewer 2:

The reviewer said that this project seeks to stabilize high-energy density LLS structures, by utilizing an in situ grown spinel phase. The reviewer remarked that this effort could offer competitive cathode energy densities, but additional development is clearly needed. The reviewer commented that some effort should be recognized to reduce the use of Co and other high-cost elements in future work. The reviewer also noted that there should be some discussion of scalability of the synthesis methods if these materials are to be industrially relevant.

Reviewer 3:

The reviewer stated that cycling stability of Co-based spinel compounds is greatly improved by cation substitution, particularly with Al, and precise synthesis control approaches. The reviewer commented that full cell performances of LLS cathodes are significantly improved by surface treatment and electrolyte additives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said the current resources appear sufficient, but there could be an opportunity to promote further collaboration with partners that have complementary synthetic experience in particle growth processes. The reviewer commented that more resources may benefit this effort.

Reviewer 2:

The reviewer noted that the resources from national laboratories and universities, including research staffs and equipment, are sufficient for the project to achieve the overall goals on time.

Reviewer 3:

The reviewer noted that the project has achieved all three milestones.

Presentation Number: bat240
Presentation Title: High-Energy Anode Material Development for Lithium-Ion Batteries, Cary Hayner, Sinode Systems
Principal Investigator: Cary Hayner (Sinode Systems)

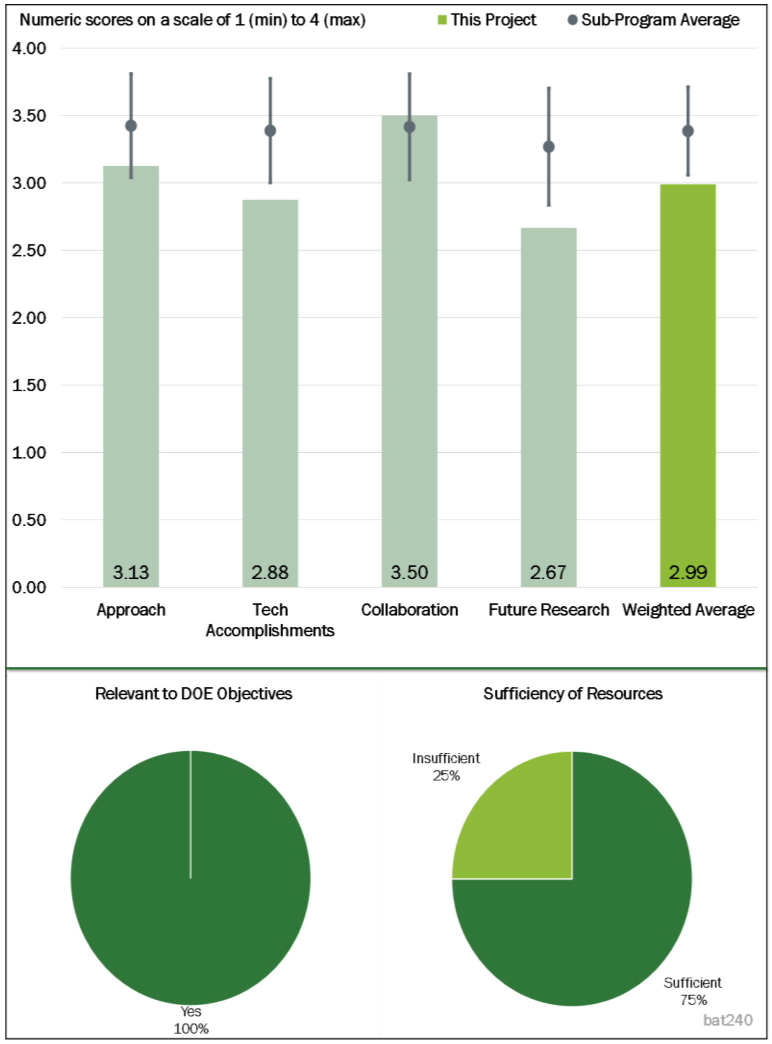

Figure 2-13 - Presentation Number: bat240 Presentation Title: High-Energy Anode Material Development for Lithium-Ion Batteries, Cary Hayner, Sinode Systems Principal Investigator: Cary Hayner (Sinode Systems)

Presenter

Cary Hayner, Sinode Systems

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The review explained that this is an organized project for the fabrication of the anode material, testing different formulations for the core material (Si-graphene) and adding different kinds of multilayer coatings, and selecting the best one based on cycle life and performance.

Reviewer 2:

The reviewer indicated that a good job is being done with respect to scale-up but the project is very far from demonstrating a significant chance that cycle life targets will be met.

Reviewer 3:

The reviewer would like to see Si-anode developers in general, and Si-Node in particular, address cell dimensional changes over life of cell, capacity recovery on aging and cell abuse tolerance. The reviewer said Si-Node did mention 80% capacity recovery 30 days at 60°C, which is better than nanowire structures.

Reviewer 4:

The reviewer reported that the technology is based on coating Si with graphene and optimizing the electrolyte to improve the cell. Although there seemed to be a fair amount of engineering to overcome challenges, it was not clear how transferable these solutions would be to real cells under real conditions.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer observed good progress on reducing graphene raw material cost and transition to water-base and high solid coating and that meeting cycle life has required blending the Si-anode with graphitic C. The reviewer added that progress would be easier to see if the capacity retention plots included the electrode loading and composition information.

Reviewer 2:
The reviewer commented that 1-Ah Li-ion cells have been tested and fabricated and the team is on track to fabricate 10-Ah Li-ion cells on schedule. However, cycling life of fabricated cells is less than 500, which needs to be improved to achieve commercial battery life-cycles. The reviewer added that the cycle life has been improved adding to the starting core material coating layers.

Reviewer 3:
The reviewer remarked that the project seemed to make progress to addressing performance goals though it was not clear where this technology is compared to state of the art.

Reviewer 4:
The reviewer did not see significant progress in cycle life, which is the single biggest challenge. The reviewer noted that mostly, the project showed that things do not get worse with scale-up.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer noted well-organized collaboration and coordination with other institutions in the fabrication process.

Reviewer 2:
The reviewer asserted that PPG and A123 are fine choices and that the project should partner with the Si deep dive to evaluate materials.

Reviewer 3:
The reviewer pointed out that SiNode has strong partners in PPG and A123 and is actively reaching out and engaging partners and potential customers. However, collaborator roles/inputs were not apparent in the presentation.

Reviewer 4:
Good partnerships were observed by this reviewer, but it was unclear how the partners are contributing or coordinating.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated the project is near completion.

Reviewer 2:
The reviewer remarked that it is unclear how further optimization will be performed and that the cells continue to lose capacity despite changes. The reviewer questioned how the project team identifies and plans to address the losses.

Reviewer 3:
The reviewer did not get a sense that the project team has a plan for how to achieve better cycle life.

Reviewer 4:
The reviewer explained that proposed future research on material development does not show recommendations based on the acquired experience in the present work and that the recommendations are too general, such as evaluate alternative structure for significant cycle life improvement or improve active material formulation and coating/barriers to extend cycle life.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented the project is clearly pointing on the development of Li-ion cell with higher performance than the actual commercial ones.

Reviewer 2:
The reviewer indicated that Si anodes in principle provide significantly higher energy density.

Reviewer 3:
The reviewer highlighted Si as one of the few materials capable of reaching the energy densities required in the future.

Reviewer 4:
The reviewer noted the DOE VTO has invested significantly in Si anodes to meet EV battery cost and specific energy goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer reported that the program is 90% complete and the available resources were sufficient.

Reviewer 2:
The reviewer said the resources seem sufficient to accomplish the goals.

Reviewer 3:
The reviewer had nothing to report.

Reviewer 4:
There were no indications detected by this reviewer that the stated milestones can be met.

Presentation Number: bat241
Presentation Title: Advanced High-Performance Batteries for Electric Vehicle (EV) Applications
Principal Investigator: Ionel Stefan (Amprius)

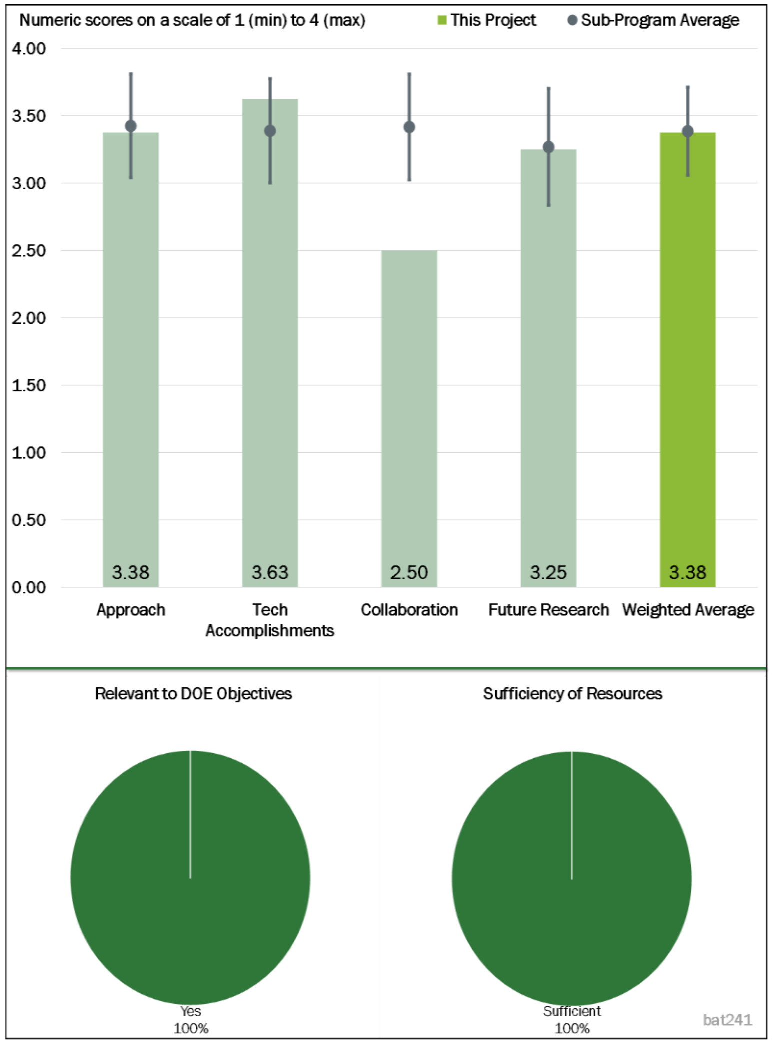

Figure 2-14 - Presentation Number: bat241 Presentation Title: Advanced High-Performance Batteries for Electric Vehicle (EV) Applications Principal Investigator: Ionel Stefan (Amprius)

Presenter

Ionel Stefan, Amprius

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer described the strategy as a good one—the project team controls the density of the Si nanowires and their length to maximize ion transport and avoid Si-Si "collisions."

Reviewer 2:

The reviewer indicated that the barriers were addressed effectively, and most of the objectives were reached.

Reviewer 3:

The reviewer asserted that the team has clearly made significant efforts and developing scale-up and the gassing seems to be a problem. The reviewer noted the approach to this using purely additives seems one track. The reviewer suggested the project team expand the pathways to deal with gassing and perhaps interact with DOE deep dives.

Reviewer 4:

The reviewer commented that the calendar life was identified as concern and that calendar life improvement to capacity recover was presented but needs more work. The reviewer also noted, the cell dimensional change/tolerance was not reported. The reviewer said the Amprius anode structure and porosity may be beneficial for this criterion and that progress on gas evolution was also reported but not substantiated—this is a key technical advance for high-energy prismatic pouch cells with high Ni cathode + Si anode. The reviewer noted that the principal investigator (PI) verbally noted good results in abuse testing 10 amp hour (Ah) cells at Sandia National Laboratories (SNL) and that this should be reported along with details of the cell design and test conditions. The reviewer would be interested to hear what Si % utilization is in the cell.

The reviewer pointed out that the cathode work, if any, was not really clear, and that some data seemed to be a high-voltage LCO cathode, which is a non-starter for VTO-relevant markets.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer observed considerable progress being made in all of the gap areas, and noted that performance at low temperature is not really satisfactory for any cells.

Reviewer 2:
The reviewer noted that the project is developed according to the milestones and the planned time, and that there has been important progress in increasing energy density, specific energy, and cycle life.

Reviewer 3:
The reviewer still had concerns with gassing, and noted that more focus on, and new ways to address this, is needed.

Reviewer 4:
The reviewer reported that calendar life was identified as a concern and that calendar life improvement to capacity recover was presented but needs more work. The reviewer noted that progress on gas evolution was also reported but not substantiated and that this is a key technical advance for high energy prismatic pouch cells with high-Ni cathode + Si anode. The reviewer said the PI verbally noted good results in abuse testing 10Ah cells at SNL and that this should be reported along with details of the cell design and test conditions.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer indicated that the project team has worked with several partners for the development of cathodes and electrolytes.

Reviewer 2:
The reviewer described collaboration as limited, but acknowledged that the program was single awardee.

Reviewer 3:
Although many companies were listed, this reviewer was unsure of the efforts or significance.

Reviewer 4:
The reviewed noted that the project has no partners and that this can be a fairly serious drawback because it could mean that the project team does not understand what the market is demanding. The reviewer said it can also mean that the project team is not aware of some technologies that could help advance towards the project goals. The reviewer stated the fact that the project team "work with multiple partners" does not necessarily mean very much at all.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the project correctly proposed how to face the barriers in the future, and asserted that the collaboration with the other participants will be very useful to complete the project within established targets.

Reviewer 2:
The reviewer gave the project team a high score here because the project team has a good record of year-to-year improvement. However, the reviewer noted, the project team does not indicate how they will try to overcome the cycle and calendar life problems.

Reviewer 3:
The reviewer noted that the project team should think about alternative ways around the problems it is having, and that the team should maybe focus on standard cathodes to deal with only one electrode problem.

Reviewer 4:
The reviewer noted that 25% of the budget remains, but there is a 9/2018 end date and that it is not clear how the program lands on runway.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer described this project as very helpful for the DOE objectives to obtain better performance batteries that can be used in electric cars. The reviewer also noted that several promising materials are investigated in this project for the anode, cathode, and electrolyte.

Reviewer 2:
The reviewer asserted that development and demonstration of 350 Wh/kg cells and addressing gap analysis for EV application is relevant to DOE VTO objectives.

Reviewer 3:
The reviewer highlighted Si as one of the few technologies that can address future energy storage goals.

Reviewer 4:
High energy density was noted by this reviewer.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted resources are sufficient for the development of this project, allowing that all pouch cells were delivered according to milestones.

Reviewer 2:
The reviewer found no indication that new resources are necessary.

Reviewer 3:
The reviewer stated $5 million for single company program could be challenged, but the company provided 50% cost share.

Reviewer 4:
Sufficiency of resources was described by this reviewer as self-explanatory.

Presentation Number: bat247
Presentation Title: High-Energy Lithium Batteries for Electric Vehicles
Principal Investigator: Herman Lopez (Envia Systems)

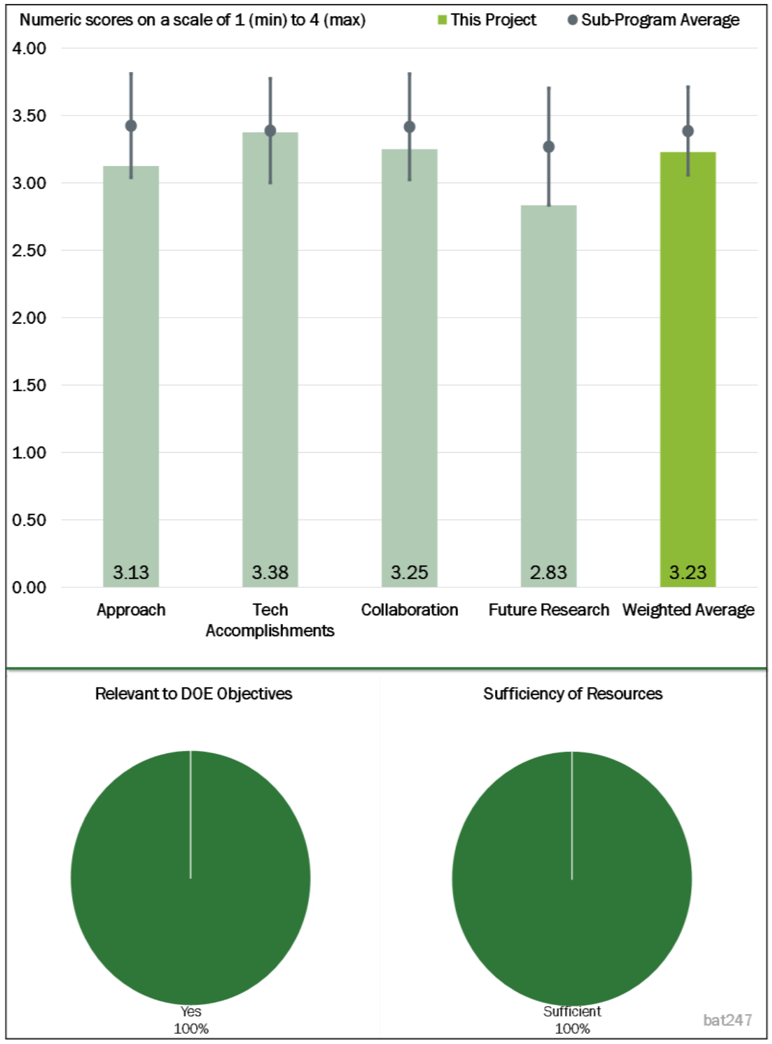

Figure 2-15 - Presentation Number: bat247 Presentation Title: High-Energy Lithium Batteries for Electric Vehicles Principal Investigator: Herman Lopez (Envia Systems)

Presenter

Herman Lopez, Envia Systems

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer was very impressed with the progress this year, and would like to see calendar life measurements.

Reviewer 2:

The reviewer reported the project team aims to make incremental progress by combining their own work with the best available from collaborators.

Reviewer 3:

The reviewer explained that this project focuses on increasing the battery capacity and that other objectives, such as specific energy and life-time, are not given much effort. The reviewer also noted plots should be redone for a presentation and not simply copied/pasted from other sources because several of them are unreadable.

Reviewer 4:

The principal concern indicated by this reviewer is that this appeared to be a cathode screening exercise and the poster did not make clear what development/advances were accomplished. The reviewer noted that was an absence of even rudimentary cell chemistry or non-proprietary data on electrode design variables and the influence on performance makes this difficult to understand what work was performed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer asserted that the project team has made outstanding progress, and the reviewer would like to see calendar life tests and elevated temperatures.

Reviewer 2:
The reviewer reported that very good results have been obtained, closing in on 300 Wh/kg and that 700 cycles is probably more than sufficient.

Reviewer 3:
The reviewer stated that some of the USABC EV cell targets for 2020 have not been accomplished yet, principally the life-time of 1,000 cycles. No results on the economical pre-lithiation process were observed by this reviewer. However, some goals such as the large capacity battery and 80% of SOC in 15 minutes have been achieved.

Reviewer 4:
Progress on cell fixturing, scale up, and gassing was reported but not translated to practicality/impact in a vehicle battery pack, which this reviewer described as an apparent significant advance in incorporating high fraction of SiO_x with unknown approach to prelithiate or manage irreversible capacity loss (ICL). The reviewer noted the fast-charge results are impressive and meaningful, but would like an explanation of how or the cycle life.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that Zenlabs has several partners and each one is specialized in building a specific part of the battery or manufacturing the cell or testing the battery. The reviewer noted the task distribution is excellent and all the partners are well-coordinate to each other.

Reviewer 2:
The reviewer observed good coordination with partners though the reviewer is not sure where pre-lithiation partner is coming in.

Reviewer 3:
The reviewer remarked that the project team seems to have organized an excellent collaboration, but the reviewer does not see what the project team is contributing, other than organizing these collaborators to all work together.

Reviewer 4:
Aside from Slide 5, it was not really clear to this reviewer what the roles were, beyond supplier.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer reported that the program is ended/under a no-cost extension.

Reviewer 2:
The reviewer stated the project is mostly over and it looks like the big issue is what works best and would it apply to other systems.

Reviewer 3:
The reviewer noted this is the last year (out of 4) and all the proposed future research is completed. The reviewer also noted the project team did not propose anything new to help to overcome the barriers.

Reviewer 4:
The reviewer did not see any ideas for how to make the project team's results any better, other than downselecting from among the samples that the project team already have.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer indicated that development and demonstration of large-format, high-energy cells supports DOE objectives related to EV adoption and domestic cell production.

Reviewer 2:
The reviewer explained that the project addresses the majority of the DOE goals such as life-time, specific energy, high rate charge, and others; however, not all goals were successful but the research performed will help to accomplish the goals in the near future.

Reviewer 3:
The reviewer stated clearly this is working towards suitable approaches for high energy density.

Reviewer 4:
High energy density was noted by this reviewer.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed reasonable resources, considering the large number of partners.

Reviewer 2:
The reviewer noted a no-cost extension was requested, but it is not clear if this indicated delays due to resource availability.

Reviewer 3:
The reviewer described resources as okay.

Reviewer 4:
Resources were fine from this reviewer's perspective.

Presentation Number: bat252
Presentation Title: Enabling High-Energy, High-Voltage Lithium-Ion Cells for Transportation Applications: Electrochemistry and Evaluation
Principal Investigator: Daniel Abraham (Argonne National Laboratory)

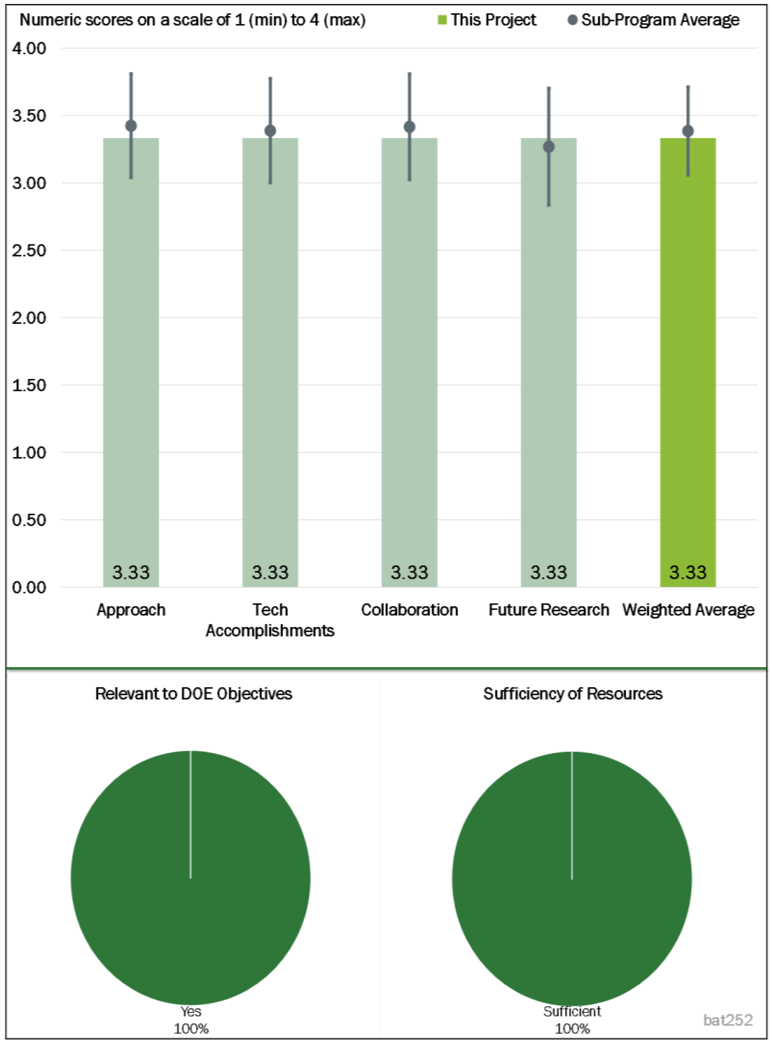

Figure 2-16 - Presentation Number: bat252 Presentation Title: Enabling High-Energy, High-Voltage Lithium-Ion Cells for Transportation Applications: Electrochemistry and Evaluation Principal Investigator: Daniel Abraham (Argonne National Laboratory)

Presenter
Adam Tornheim, Argonne National Laboratory

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer believed the approach taken was excellent. It proceeds in a logical manner and a wide array of characterization techniques were used to gain a better understanding of the challenges confronting the next-generation of electrode materials.

Reviewer 2:
The reviewer said this project is well-designed and supportive of modeling and materials characterization by collaborators. Generating a figure of merit for energy and power of a standard cell with different electrolytes is a critical need. The reviewer added it would be particularly desirable to share the protocol for determining these figures of merit (FOMs) with the community to standardize such evaluations. One drawback of this approach is the inherent interplay between the electrode material(s) chosen in the standard cell and the electrolyte. In essence, what might work for lithium-iron phosphate (LFP) would not be the same as LMO or Li NMC. Similarly, different graphites would exhibit different FOMs with the same electrolyte. The reviewer said the key novelty of this work is in the determination of electrolyte additive passivation mechanisms. Studies of NMC gassing at high voltages and Mn dissolution, while important, are somewhat duplicative of what is already in the published literature. The reviewer described the AEGIS system as interesting from a research standpoint, but its benefits over standard differential electrochemical mass spectrometry (DEMS) techniques remain unknown (or merely unexplained).

Reviewer 3:
The reviewer asserted that this was a very good overview of a number of separate research areas related to electrolyte interactions. The reviewer noted it was presented essentially as an overview of disparate areas of

work, and could have benefited from a higher-level dialogue on the overarching theme and how these various topics may tie together as it was a little difficult to get the detail on any one topic.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that this project has made excellent strides toward aggregating understanding of electrolyte additive function. The reviewer noted that more work needs to be done in this area, but should also be accompanied by fundamental surface science studies of the sort that this project has tackled (i.e., on tris(2,2,2-trifluoroethyl) phosphite [TTFP]). The evaluation of fluorinated electrolytes is similarly important. The reviewer stated the PIs should be aware, however, of several trends in industry away from prohibited or potentially harmful compounds (i.e., sulfones, Poly[ether sulfones]).

Reviewer 2:

The reviewer explained that the project accomplishments provide great insights to understand the interfacial reactions between electrolyte and electrode materials as well as the role of electrolyte additives to the electrochemical performance of Li-ion batteries. This insightful understanding will guide the future investigation to optimize the development and synthesis of electrolyte for high-energy density batteries.

Reviewer 3:

The reviewer noted that several interesting areas of work were discussed. The observation of dramatically different behavior due to the formulation of the electrolyte in pre-formed solid electrolyte interface (SEI) layers was not necessarily a surprise, however quite interesting none the less. The reviewer noted significant follow up on this work could provide some interesting mechanistic understanding of this interesting phenomenon. Again, several topics showed interesting results, but with little cohesion between topics.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that collaboration is strong across the project team.

Reviewer 2:

The reviewer said this project was collaborated among many national laboratories and universities as shown in the presentation.

Reviewer 3:

The reviewer commented that this work was obviously accomplished with a large number of competent research components, but that it did not necessarily appear that the project team was coordinated in a strong way. This does not suggest the work was not of high quality, simply that coordination of the different components was not evident.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

Overall, this reviewer described the proposed future work as excellent. The reviewer suggested the PIs could pay more attention to the understanding of interface evolution, especially the interfaces of cathode/electrolyte and anode/electrolyte. Probably, techniques of high-resolution transmission electron microscopy (HRTEM) and/or soft XAS can provide more insightful information.

Reviewer 2:

The direction of the program appeared sound to this reviewer and in line with overall research goals in the field.

Reviewer 3:

The reviewer remarked that suggestions for future work are largely continuations of current efforts to understand electrolyte passivation/degradation mechanisms and the influence of gassing. This work is complementary to modeling and materials characterization efforts and so should also seek to understand the interplay of electrode coatings on electrolyte behavior. The reviewer added an improved understanding of formation mechanisms at various temperatures would be valuable. Such work was started by looking at impedance as a product of calendar aging.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer described this project as very important and extremely relevant to DOE objectives that may guide the design of electrolytes that support higher energy density battery materials.

Reviewer 2:

The reviewer stated the overall DOE target is to develop Li-ion batteries with low-cost, high energy density and electrochemical properties. This project’s focus, developing high voltage electrolyte additives and understanding the reactions between electrolyte and electrode materials, is consistent with DOE’s goals.

Reviewer 3:

The reviewer said that developing a modeling component of complex materials behavior is a relevant area of research.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer observed sufficient resources from many national laboratories and universities to support the research work of this project.

Reviewer 2:

The reviewer described project resources as sufficient.

Reviewer 3:

The reviewer had no special comments on resources.

Presentation Number: bat253
Presentation Title: Enabling High-Energy, High-Voltage Lithium-Ion Cells for Transportation Applications: Theory and Modeling
Principal Investigator: Hakim Iddir (Argonne National Laboratory)

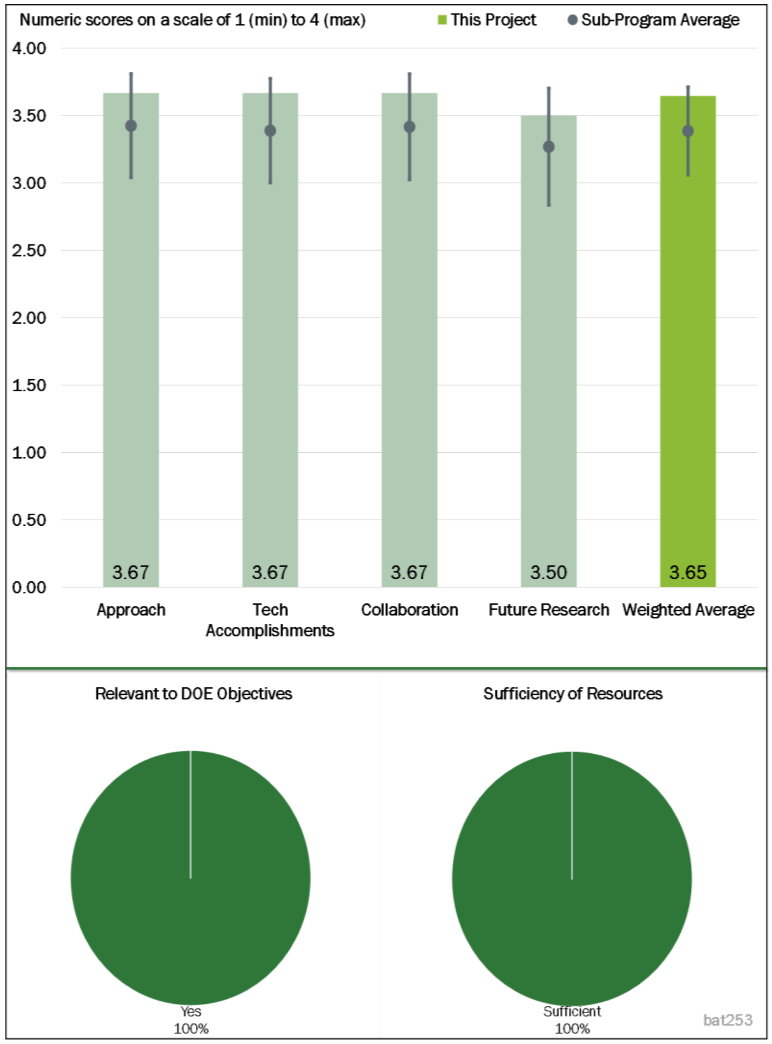

Figure 2-17 - Presentation Number: bat253 Presentation Title: Enabling High-Energy, High-Voltage Lithium-Ion Cells for Transportation Applications: Theory and Modeling Principal Investigator: Hakim Iddir (Argonne National Laboratory)

Presenter

Hakim Iddir, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer indicated that the project is both well-designed and well-executed with a sharp focus on details that impact NMC stability and interaction with the electrolyte. Experimental work complements the simulation approach, which keeps it reasonably grounded. The reviewer added even stronger support from experiment is desirable in the future.

Reviewer 2:

The reviewer stated that this program, related to fundamental modeling studies of complex battery materials issues, was well laid out and explained. The reviewer noted this is very complex work but the components of the program, including assumptions and limitations, was competently addressed. Comparisons of modeling outcomes versus experimental observation were an important part of the presentation.

Reviewer 3:

The reviewer explained that this project applied atomistic modeling approach for a theoretical prediction of the interfacial reactions between electrolyte and additive with cathode materials, which guide the design and synthesis of electrode material and electrolyte. This approach is highly linked with the real experimental work.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that this program has moved the ball forward with some legitimate comparisons of simplified particle models versus observed physical phenomenon. The question of whether the modeling can be predictive rather than confirming remains open; however, this is a solid base to continue work.

Reviewer 2:
The reviewer asserted that each individual topic is of interest to researchers working in the field and has produced novel conclusions. Particular emphasis is placed on TM segregation near surfaces and the mechanism of trimethoxypropylsilane (TMPSi) passivation on NMCs, which should be relevant for the future design of cathode coatings or electrolyte additives. The reviewer noted that if some of these conclusions can be generalized for a larger group of coating species (i.e., beyond alumina) or additives, it will be even more relevant for application.

Reviewer 3:
The reviewer remarked that this program meets a need by linking the experimental research and theoretical mechanism understanding, which is critical to design novel high-energy density, high-performance cathode materials for lithium ion batteries.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer emphatically described collaboration and coordination across the project team as outstanding and added that the strength of this project team is in its varied approaches and independent research topics that still hew to the theme of enabling higher energy cathode materials.

Reviewer 2:
The reviewer stated the appropriate level of collaboration appears to have been applied and that comparisons of modeling with experimental observation appear to have been well coordinated.

Reviewer 3:
The reviewer said this project was collaborated among many national laboratories and universities as showed in the presentation.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that overall the proposed future work is excellent. The reviewer suggested the PIs could pay more attention to link this project with the related experimental work in BAT 252 and BAT254 and show how this theoretical modeling can support those projects.

Reviewer 2:
Proposed future work was described as generally interesting by this reviewer, who expressed confidence in the researchers' ability to extend these results by exploring other cathode surface interactions. The reviewer noted input from industry on relevant cathode coating materials (i.e., lithiated oxides) and processes (i.e., aqueous or non-aqueous sol gel) could be valuable to design simulations based on real systems, and exploring the impact of binder chemistry and location may also be interesting.

Reviewer 3:
Program direction appeared sound and in line with overall research from this reviewer's perspective.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer remarked that this project is very important and extremely relevant to DOE objectives to enable higher energy, longer cycle life cathode materials.

Reviewer 2:
The reviewer stated DOE's overall target is to develop Li-ion batteries with low cost, high energy density, and electrochemical properties, and this project's focus, modeling the interfacial reactions between electrolyte and high-energy density electrode materials, is consistent with DOE's goals.

Reviewer 3:
The reviewer asserted that developing a modeling component of complex materials behavior is relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted the resources from many national laboratories and universities are sufficient to support the research work of this project.

Reviewer 2:
The reviewer said the resources for this project are sufficient.

Reviewer 3:
The reviewer had no significant comment on resources.

Presentation Number: bat254
Presentation Title: Enabling High-Energy, High-Voltage Lithium-Ion Cells for Transportation Applications: Materials Characterization
Principal Investigator: John Vaughey (Argonne National Laboratory)

Presenter

John Vaughey, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

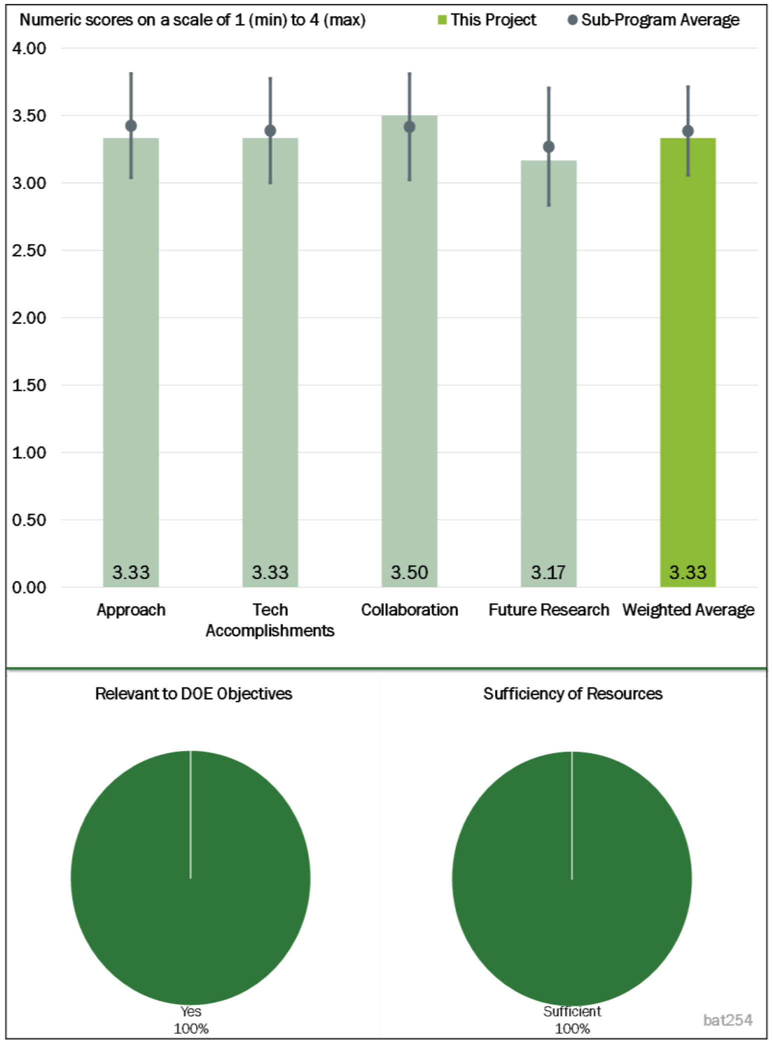

Figure 2-18 - Presentation Number: bat254 Presentation Title: Enabling High-Energy, High-Voltage Lithium-Ion Cells for Transportation Applications: Materials Characterization Principal Investigator: John Vaughey (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said the project is well-designed and well-executed with an interesting focus on understanding the role of alumina coatings on NMC cathode materials. The structure of various alumina coatings has been evaluated by solid-state NMR, electrochemistry and microscopy, revealing that the underlying composition of NMC (e.g., the concentration of Mn) is a critical variable in the coating structure and effectiveness. The effectiveness of annealing and original solution-based deposition method is also important to establish functionality. While the heavy use of NMR is informative, complementary surface science techniques, perhaps with depth profiling, would be helpful to confirm and understand changes in TM oxidation state. The development of thin film deposition techniques should allow these surface science studies in future work—but comparison to bulk synthesized particles may be a challenge.

Reviewer 2:

The reviewer stated the program sets out a reasonable goal of understanding and characterizing aluminum oxide (Al_2O_3) surface coatings on various NMC structures, which follows from a fairly well-known commercial use of this system in cobalt oxide systems. The reviewer added that, in general, this study takes the correct path toward characterization and understanding the differences between the two systems.

Reviewer 3:

The reviewer indicated that this project applied a wide array of characterization techniques as well as electrochemical models for a better understanding of the reaction mechanisms of high-energy density cathode materials in Li-ion batteries.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer described technical accomplishments and progress as excellent. It proceeds in a logical manner and the team used many characterization techniques to gain a full understanding of the structural information of the cathode materials with various doping/synthesis approaches and interfacial reaction with electrolyte. The reviewer said that all of the achievements are critical to realize the overall goals of the projects.

Reviewer 2:

The reviewer commented that results from the past year are valuable and will undoubtedly help in the design of new cathode coating materials or techniques. The reviewer added it would be useful to generalize these results for more than a single coating chemistry. The relationship of Mn concentration could be relevant to a subset of coating materials but not to others. Because other work in this area has also explored Ti, niobium (Nb), tantalum (Ta), etc. based coatings, broadening the type of coatings studied may be of commercial interest.

Reviewer 3:

The reviewer notes the outcome appears to be quite apparent that there are significant chemical differences in the way alumina interacts with the NMC systems. In particular, performance gains are neutral to negative, with performance trending down as higher Ni content materials are evaluated. The reviewer stated the proposed mechanisms for this appear reasonable.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer observed exceptionally strong collaboration across the project team.

Reviewer 2:

The reviewer stated the appropriate level of collaboration appears to have been applied and critical electrochemical testing of the systems was done appropriately.

Reviewer 3:

The reviewer indicated that this project was collaborated among many national laboratories and universities as shown in the presentation.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer opined that suggestions for future work are interesting and could be valuable, particularly related to coating-electrolyte synergy. Further exploration of surface charge could be useful, but would have to be conducted using a new set of characterization techniques beyond NMR. In situ or operando (e.g., with electrolyte) studies of surface states would be most relevant, if possible.

Reviewer 2:

The reviewer noted the direction of the accomplished work seems to suggest that the alumina coating system is not necessarily a fundamentally compatibly system with the NMC systems under study. The reviewer added it seems that the team should give some careful thought to justify future directions this work might take on, and questioned is this system can be studied further as indicated or if other coating system be evaluated.

Reviewer 3:

The reviewer said the proposed future work is consistent with the current project direction, which should provide deeper and wider understanding of the high-voltage, high-energy density cathode materials.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer indicated that this project is very important and extremely relevant to DOE objectives to enable higher energy, longer cycle life cathode materials.

Reviewer 2:

The reviewer asserted that improvement of high-Ni NMC systems is very relevant to the DOE.

Reviewer 3:

The reviewer stated DOE's overall target is to develop Li-ion batteries with low-cost, high-energy density and electrochemical properties, and this project's focus, characterizing the interfacial reactions of high-energy density Ni-rich cathode material, is consistent with DOE's goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer observed sufficient resources for this project.

Reviewer 2:

The reviewer noted sufficient resources from many national laboratories and universities to support the research work of this project.

Reviewer 3:

This reviewer had no significant comment.

Presentation Number: bat263
Presentation Title: Electrodeposition for Low-Cost, Water-Based Electrode Manufacturing
Principal Investigator: Stuart Hellring (PPG Industries)

Presenter

Stuart Hellring, PPG Industries

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed a very good approach to developing an electrodeposition-based method for depositing Li-ion electrode suspensions onto current collectors.

Reviewer 2:

The reviewer indicated that the technical approach addressed battery production cost by developing thick electrode via aqueous processing.

Reviewer 3:

The reviewer noted minimal justification for this work other than concern regarding volatile organic compounds.

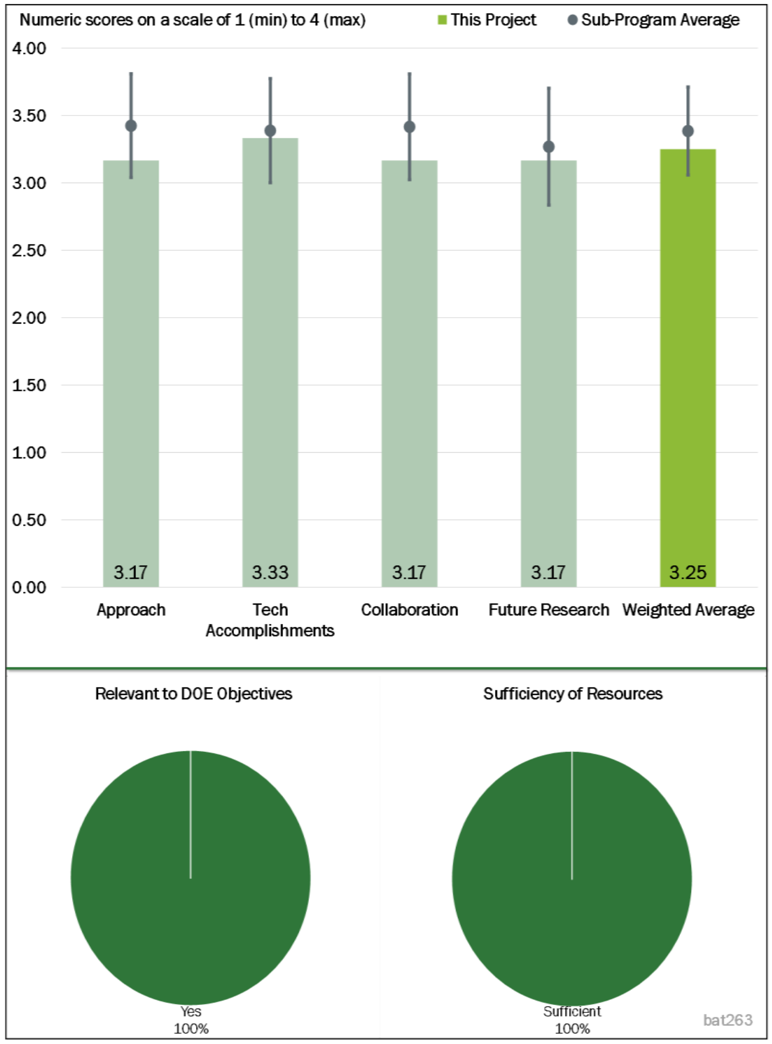

Figure 2-19 - Presentation Number: bat263 Presentation Title: Electrodeposition for Low-Cost, Water-Based Electrode Manufacturing Principal Investigator: Stuart Hellring (PPG Industries)

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted very good progress demonstrated to date. Really good and disruptive technology to replace slot dye coating methods, and to replace the toxic N-Methyl 2-Pyrrolidone (NMP) solvent with aqueous ones. The reviewer added the challenge is that one is still dependent on the same mix, coat, dry, calendar process. The only process step that is impacted is the coat step. Critically, this enables much thicker coatings, 2x that of NMP based solvent electrodes. This is important in that it gives us a new way to coat electrodes.

Reviewer 2:

The reviewer noted that, given the boundaries for this project, the project team established an excellent approach and the results of work yielded a level of success. However, the project team actually fails to indicate whether or not go/no-go state has been achieved. The reviewer stated that any work must have valid and specific metrics prior to funding a work-plan.

Reviewer 3:

The reviewer said the technical was made according to plan, although the production cost savings may be not huge.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that PPG is working with ANL, ORNL, and Navitas, which is excellent. The reviewer encouraged PPG to collaborate with Lambda Tech to implement microwave assisted drying to make sure PPG has very good high loading electrodes—the Lambda tech drying approach is particularly valuable for thick electrodes.

Reviewer 2:

The reviewer described the partners as well-coordinated.

Reviewer 3:

The reviewer reported that an industrial partner is contributing to project. However, what is needed is whether this project is economically justified.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

In addition to the very relevant planned future research, this reviewer explained that the project should focus in the near-term on new capabilities that this technology could bring, such as controlled porosity, electrode structures for fast-charge, etc. The reason this reviewer mentioned this is because the reported cost savings of 1.8% at the cell level is almost certainly too little to entice a large call manufacturer to implement a brand-new technology.

Reviewer 2:

The reviewer commented that battery energy density appears to be more important than energy density for vehicle applications due to limited packing space, and that the project team may want to show the energy density of the cell with the new manufacturing processing compared to that of the base cell. The reviewer added that there are no explicit details about the uniformity of the electrode with the developed aqueous process.

Reviewer 3:

The reviewer observed a reasonable work-plan proposed by the project team, and suggested that it survey the industry at large to determine the best direction to take.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewed remarked that the project is very relevant in many areas of DOE technical roadmap.

Reviewer 2:

The reviews pointed out that the project supports the goals for battery manufacturing cost reduction.

Reviewer 3:
The reviewer noted the work meets DOE needs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted appropriate resources and added, it would be good or DOE to find a way to support this type of disruptive technology going forward.

Reviewer 2:
The reviewer noted the resources appear to be sufficient for the proposed efforts.

Reviewer 3:
The reviewer said yes.

Presentation Number: bat264
Presentation Title: Lithium-Ion Battery Anodes from Electrospun Nanoparticles/Conducting Polymer Nanofibers
Principal Investigator: Peter Pintauro (Vanderbilt University)

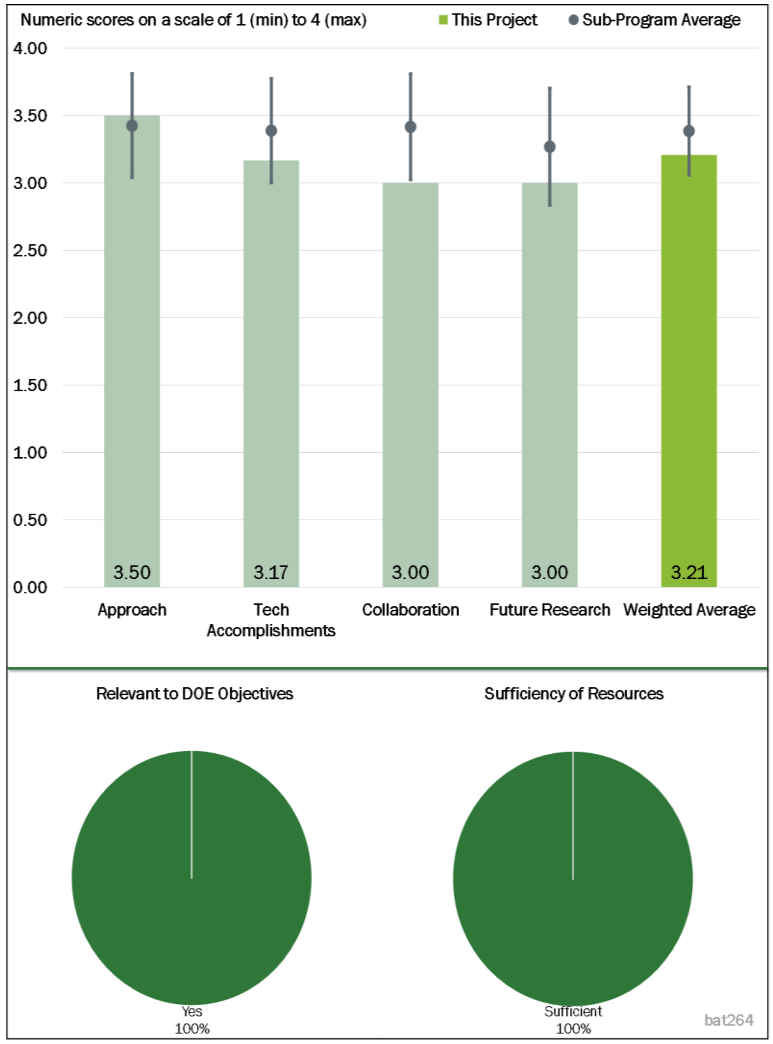

Figure 2-20 - Presentation Number: bat264 Presentation Title: Lithium-Ion Battery Anodes from Electrospun Nanoparticles/Conducting Polymer Nanofibers Principal Investigator: Peter Pintauro (Vanderbilt University)

Presenter
Peter Pintauro, Vanderbilt University

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer pronounced the approach to developing electrospun Si-based anodes to be good.

Reviewer 2:
The reviewer said that the technical approach addressed capacity-fade barriers for a Si anode-based, high-energy battery.

Reviewer 3:
The reviewer commented that the approach is both novel and presents an opportunity to achieve enhanced manufacturability of battery membrane composite structures.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer stated that the team has made significant progress towards its goals.

Reviewer 2:
The reviewer said that the technical progress is reasonable and aligns with the plan.

Reviewer 3:
The reviewer commented that the approach is not a bad way to manufacture Si-based anodes, but opined that there is just not a critical advantage here to convince the reviewer that this will be successful when other Si approaches have not been. The reviewer saw the biggest issue here as the lack of SEI stabilization with Si-

based anodes (see Slide 15). The other issue, more critical for consumer electronics applications, is volume expansion of the electrode, but this manufacturing approach does not address that either.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration across the team members appeared excellent to the reviewer.

Reviewer 2:
According to the reviewer, project assignments have been made and the team appears to communicate issues and results.

Reviewer 3:
The reviewer had no issue with collaboration, but suggested that it would be advantageous if Vanderbilt can determine how this approach can address the two main issues with SI-based anodes.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the course is set to continue work. The team also needs to assess efforts made by other researchers outside of project team.

Reviewer 2:
The reviewer noted that battery energy density appears to be important for vehicle applications due to limited packing space. The reviewer suggested that the contractor may want to show the energy density of the cell with the new manufacturing processing compared to that of the base cell. The reviewer hoped to see more interactions with industry and a future plan for potential transition.

Reviewer 3:
The reviewer referenced prior comments.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
Enabling low-cost Si anodes is certainly relevant, according to the reviewer.

Reviewer 2:
The reviewer stated that the project supports the goals for an increase in battery specific-energy density.

Reviewer 3:
The reviewer remarked that advancements in energy storage are important to future energy developments.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources appeared to be sufficient to the reviewer for this project.

Reviewer 2:
The reviewer stated that all is adequate.

Reviewer 3:

The reviewer thought that resources were okay.

Presentation Number: bat266
Presentation Title: Co-Extrusion (CoEx) for Cost Reduction of Advanced High-Energy and High-Power Battery Electrode Manufacturing
Principal Investigator: Ranjeet Rao (PARC)

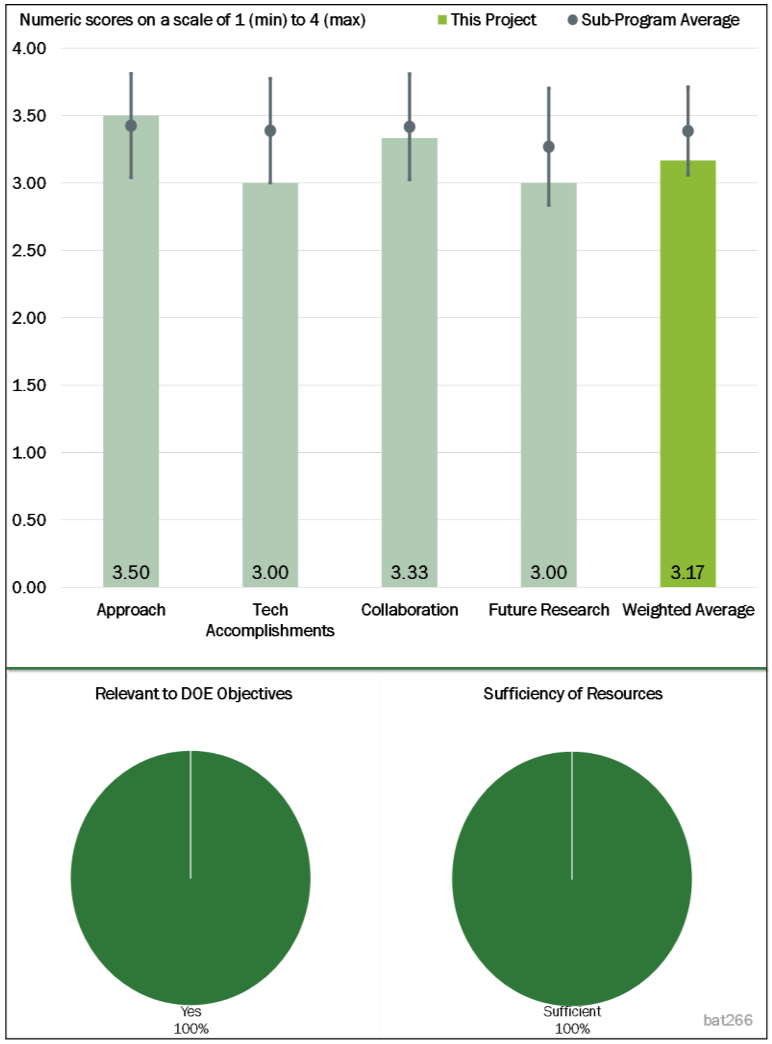

Figure 2-21 - Presentation Number: bat266 Presentation Title: Co-Extrusion (CoEx) for Cost Reduction of Advanced High-Energy and High-Power Battery Electrode Manufacturing Principal Investigator: Ranjeet Rao (PARC)

Presenter
Ranjeet Rao, PARC

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer remarked that this is a very good approach for partially decoupling power from energy through novel, co-extruded, Li-ion electrode designs.

Reviewer 2:
The technical approach addressed battery production cost by developing thick electrodes via the co-extrusion method, according to the reviewer.

Reviewer 3:
The reviewer commented that the project seemed to duplicate efforts ongoing by others and may not yield expected results in any scale-up.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer stated that the technical approach sounds productive and the progress aligns with the plan. There is not sufficient detail outlined to support the cost-reduction claims.

Reviewer 2:
The reviewer said that progress is ongoing, but only minimal results have been reported.

Reviewer 3:
The reviewer commented that the structure shown on Slide 9 will likely result in rather minimal power improvement as the “thick” regions are almost a millimeter (mm) wide. The longest distance that charging and discharging reactions will take place in a high-power (3C-4C [charge rate of 3-4]) situation is less than 100

microns. These are five times that this can be seen in the extreme fast-charging program. Thus, the reviewer concluded that these "thick" pillars should probably be about 200 microns wide or less to ensure that Li ions are able to penetrate or escape the interior regions during high power pulses. Plots on Slides 11 and 12 show this. The reviewer said that the high rate behavior of the co-extrusion (CoEx) cathodes is better than the standard ones, but they are still losing 30%-50% of their C/10 capacity at 2C.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration across the team members appeared excellent to the reviewer.

Reviewer 2:
The reviewer saw good collaborations and had no issues.

Reviewer 3:
According to the reviewer, all participants seem to be fully involved.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer was curious if an NMP-free process, such as that being studied at ORNL, can work together with CoEx for further cost reductions.

Reviewer 2:
The work plan has been established and the reviewer strongly suggested that the team create a dynamic model of "slurry" flow to better assess the likelihood of manufacturability of the reproducible electrodes at scale-up.

Reviewer 3:
The reviewer was concerned about the size of the "thick" cathode regions. The reviewer thought that they need to be much thinner. It will also be difficult to obtain good data if the anodes used in the cells are not fabricated to have similar power capability as the cathodes.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that the project fits DOE's mission scope.

Reviewer 2:
The reviewer noted that the project supports the goals for battery cost reduction and specific energy-density increases.

Reviewer 3:
The reviewer found the project to be extremely relevant as DOE is interested in enabling much thicker electrodes (for higher energy and lower cost cells) that still provide the needed power (for acceleration of the vehicle and fast-charge).

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Adequate resources are available, according to the reviewer.

Reviewer 2:
The reviewer said that the resources appear to be sufficient for the proposed efforts.

Reviewer 3:
The reviewer commented that the resources are reasonable. The reviewer supported DOE's finding a way for further funding to PARC to extend this approach to the anode and to thin the width of the thick regions.

Presentation Number: bat269
Presentation Title: An Integrated Flame-Spray Process for Low-Cost Production of Battery Materials
Principal Investigator: Chad Xing (University of Missouri)

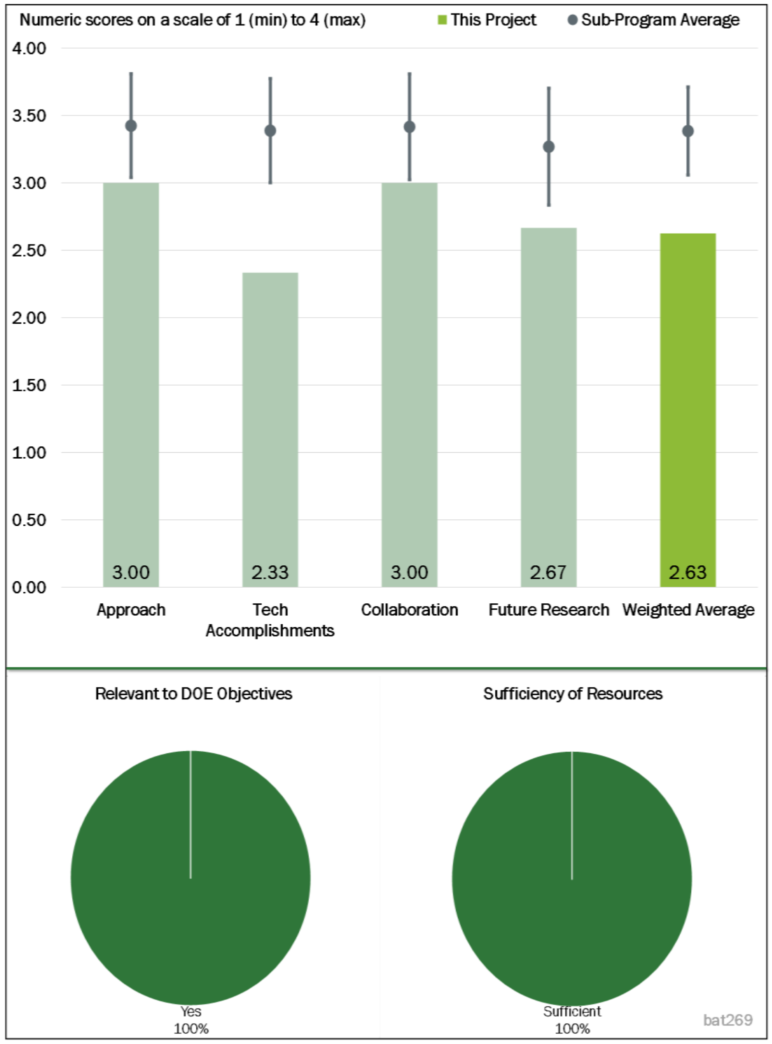

Figure 2-22 - Presentation Number: bat269 Presentation Title: An Integrated Flame-Spray Process for Low-Cost Production of Battery Materials Principal Investigator: Chad Xing (University of Missouri)

Presenter

Chad Xing, University of Missouri

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the technical approach addressed battery production cost by developing thick electrodes via an integrated flames spray process.

Reviewer 2:

The reviewer said that it is reasonable to consider novel ways to make Li-ion electrodes.

Reviewer 3:

According to the reviewer, flame spray is historically an inconsistent process with considerable waste. This, combined with issue of Li vapor pressure, raises concerns regarding process viability at scale-up for manufacturing.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found the technical progress to be reasonable though some milestones were delayed due to a major change in the flame reactor.

Reviewer 2:

The reviewer stated that the reported successes have been few. Also, the team reports need to re-evaluate go/no-go milestones involving past work.

Reviewer 3:

The reviewer remarked that there has been a very rough start to this program due to major issues with active material capacity, density, and now cell-cycle life. The team has recently increased its beginning of life (BOL) capacity to near commercial levels, which is good, but Slide 9 shows a 30% fade in 50 cycles, which is incredibly bad.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the team has designated partner assignments. Communication of work is ongoing among the team members.

Reviewer 2:

The reviewer stated that the contractor has put together a team consisting of academia and industry partners collaborating to attack the technical barriers. A future collaboration with academia, including national laboratories, is expected

Reviewer 3:

It seemed to the reviewer that this team needs help perhaps with electrode fabrication or cell construction. Eagle Picher is currently not participating at all, which may be holding the team back. The reviewer suggested trying to engage with a national laboratory electrode and cell-building team.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer mentioned that the team is simply continuing its effort based on the original work plan without extensive modification from lessons learned.

Reviewer 2:

The reviewer hoped to have seen the stability comparison for the materials produced with the developed method and the baseline materials and was curious if the process being developed can be applied to other battery materials oxides, such as LFP and LTO.

Reviewer 3:

Referring to Slide 12, the reviewer suggested not spending time and money on surface coatings until the bare NMC can perform as well as commercial powders. The coating just complicates interpretation of what is causing poor performance. Currently commercial NMC cells can cycle hundreds of times at the voltages used here. To remove the maximum voltage (V_{max}) from the fade mechanism, the reviewer urged that these cells be tested at a more reasonable 4.3V and demonstrate acceptable cycle life.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer had no issue with relevance.

Reviewer 2:

The reviewer stated that the project supports the goals for battery cost reduction.

Reviewer 3:

The reviewer remarked that battery development is with DOE mission scope.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer had no issue with resources.

Reviewer 2:
The reviewer said that the resources appear to be sufficient for the proposed efforts.

Reviewer 3:
The resources appeared to be adequate to the reviewer.

Presentation Number: bat273
Presentation Title: Composite Electrolyte to Stabilize Metallic Lithium Anodes
Principal Investigator: Nancy Dudney (Oak Ridge National Laboratory)

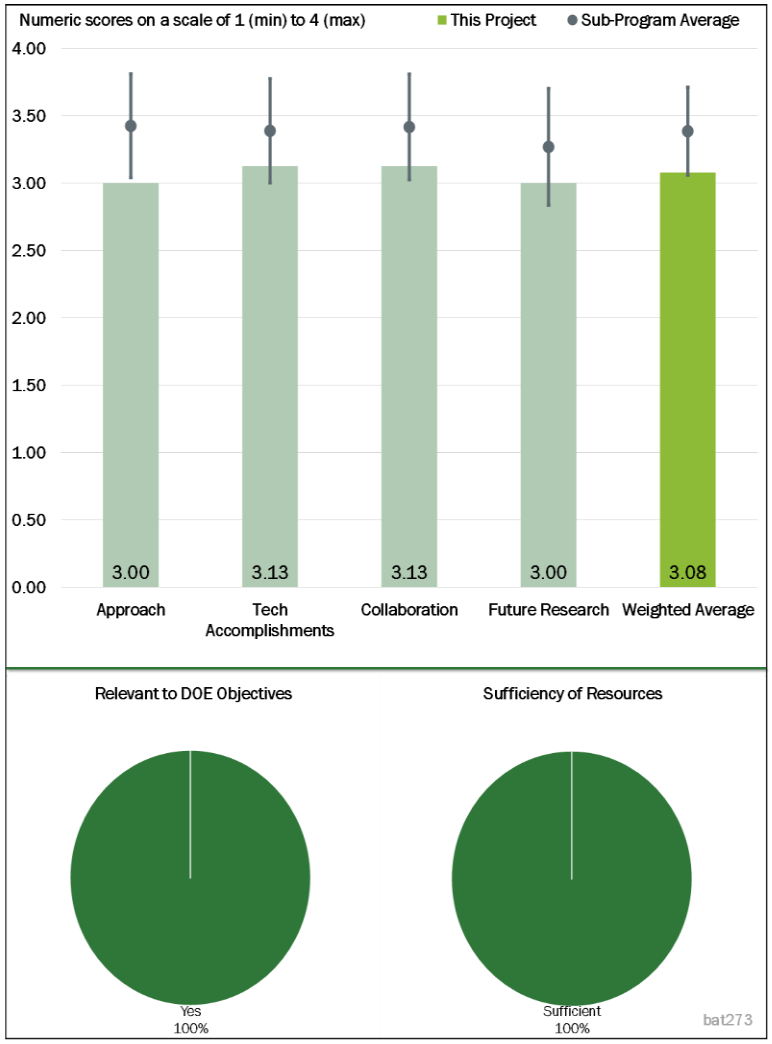

Figure 2-23 - Presentation Number: bat273 Presentation Title: Composite Electrolyte to Stabilize Metallic Lithium Anodes Principal Investigator: Nancy Dudney (Oak Ridge National Laboratory)

Presenter

Xi Chen, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that a composite electrolyte is a good way to protect a Li anode. The project approaches the goals from multiple angles and addresses the safety and efficiency barriers of Li-metal.

Reviewer 2:

The reviewer noted that the approach taken is a logical research effort for overcoming the technical barriers for Li-metal. The group is concentrating on the major factors impeding a stable electrode. The team is focusing on improving room-temperature ionic conductivity and the low-shear modulus of polymer electrolytes. The reviewer said there were efforts to include a comparison with Ohara ceramics, which is good. Identifying a suitable SSE for Li-metal anodes is paramount in order to meet VTO goals.

Reviewer 3:

The reviewer pointed out that the objective of this multi-year project is to mitigate the problems of poor cycle life, safety, and reliability with the Li-metal anode, which can potentially contribute to much higher energy densities in cells containing high-capacity cathodes (Li-sulfur or Li-air cells) through using solid-polymer electrolytes in lieu of conventional liquid electrolytes. While polymer electrolytes have advantages in electrochemical stability (with Li) and processability, ceramic electrolytes have the advantage of having a high sheer modulus. The reviewer indicated that this project is focused on developing composite solid electrolytes based on both, which however would also need an interfacial layer (in this case a polymer). Specifically, the reviewer noted that the composite solid electrolyte investigated here includes an Ohara Corporation ceramic electrolyte in high proportion blended with polyethyleneoxide (PEO)-based polymer electrolytes with a plasticizer. There is considerable contact resistance between the polymer and ceramic electrolytes, which, though reduced marginally with the use of plasticizer, is still a challenge. The reviewer did not find much novelty in this approach (a few other researchers dabbled with this approach), which is cumbersome process-wise with triple layers, and the results here are not outstanding or promising yet after as many years. Nevertheless, based on the difficulties associated with all solid-electrolyte systems, this may be a viable approach. Thus, the reviewer concluded that this project is well integrated with the other DOE VTO projects and consistent with its goals towards high specific energy density of 500 Wh/kg at the cell level.

Reviewer 4:

The reviewer said that the solid electrolyte using polymer and ceramic composite seems working, but the internal resistance is quite high. Probably because of this, no study has been done nor planned for observing Li-dendrite formation, although it is a very important barrier.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that significant accomplishments were made this year. The density of the membranes was improved by a new technique. The group published a paper in the *Journal of Power Sources.*

Reviewer 2:

The reviewer remarked that fairly good progress has been made in developing composite solid electrolytes based on PEO and an Ohara glassy electrolyte with a high proportion of solid electrolyte. The composite membrane formed by aqueous spray coating and hot pressing was found to have high density and also a high Li-transference number (compared to the polymer electrolyte). However, the reviewer commented that these composite electrolytes ended up having high contact resistance between the ceramic and polymer electrolyte, more than the bulk resistance of either polymer or solid electrolyte even with a plasticizer. The reviewer pointed out that the contact-resistance issues are no less challenging in all solid-electrolyte systems. Possibly new polymer and ceramic systems with low interfacial area-specific resistance (ASR) need to emerge to have this approach meaningful or successful. Possibly other solid electrolytes (e.g., Li lanthanum zirconate [LLZO]) with better interfacial compatibility with lithium than Ohara, could have been attempted here. Overall, the progress here is good and directed towards DOE goals of high specific energy by enabling the use of a Li-metal anode.

Reviewer 3:

The reviewer said that some results were obtained, but the ion conductivity is quite low.

Reviewer 4:

The reviewer stated that spray coating the cathode followed by the composite electrolyte shows great improvement for this Li-anode system; tri-layer cells and a tetraethylenegylcoldimethyl (TEGDME) composite electrolyte showed some promising results and can be further developed. However, all solid, full-cell performance improvement is still based on cycling at high temperature, which is also the limitation for this technology. The reviewer commented that a lot of electrochemical measurements have been performed in this project, which can provide good guidance for interfacial studies.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, there are good collaborations with researchers from ORNL, a university (Michigan State University), and industry (Ohara).

Reviewer 2:

The reviewer commented that collaboration with more agencies than last year can be seen in terms of materials preparation and characterization.

Reviewer 3:

The reviewer remarked that there is good collaboration with other laboratories. These include Jeff Sakamoto (Michigan State University), Ohara, and polymer researchers at ORNL.

Reviewer 4:

The reviewer suggested that the collaboration should be extended to accelerate the project with a stronger connection with both universities and national laboratories.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noticed that the PI knows what she is doing and this is a pretty long program, which started in 2014.

Reviewer 2:

The reviewer found the proposed efforts to be realistic and appropriate. Minimizing interfacial resistance is critical. Moving toward a polymer gel is a realistic approach.

Reviewer 3:

The reviewer noted that there are still quite a few outstanding technical barriers in the development of composite solid-polymer electrolytes that are stable with a Li anode with low interfacial resistance (ASR). The proposed future studies of assessing new chemical and mechanical treatments of the Li interface with a composite electrolyte, examining new polymer/solid electrolyte combinations, adopting a barrier layer (Li phosphorous oxy-nitride [LiPON]) over a composite polymer electrolyte to stabilize the plasticizer, and developing full cell designs by spray coating these composite membranes with higher ceramic loading with bimodal particle sizes are logical and address the key technical barriers towards using Li-metal anodes. The reviewer said that these studies are consistent with the DOE goals of high specific energy.

Reviewer 4:

The PI should try materials beyond Ohara and PEO, which is very necessary because they have been shown limited potentials. However, the PI does not specify what are the alternative materials are. The reviewer mentioned that the size of particles may be a factor but should not be too critical.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that if this project can be successful in the next few years, the impact will be huge for the field of high-energy batteries.

Reviewer 2:

The reviewer stated that this project supports DOE objectives. The types of electrolytes that the team is developing may enable using Li-metal anode, allowing for batteries with higher energy densities and enhanced safety.

Reviewer 3:

The reviewer explained that for the widespread use of EVs, the batteries need to be lightweight, compact, safe, and low cost. The state-of-the-art Li-ion batteries are inadequate to fulfil these needs. Higher specific energy density (at least 500 Wh/kg) and lower cost batteries are being developed by DOE, either with Ni-rich NMC cathodes or sulfur cathodes that needs integrating with stable Li anodes. The reviewer commented that a long-life Li anode is desired to meet the DOE goals, which this project has been addressing by aiming to develop suitable composite solid polymer electrolytes.

Reviewer 4:
The reviewer remarked that finding proper solid or composite electrolytes would definitely be a good use of Li and the anode. This should give higher capacity than a Li-ion battery.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked that the resources were adequate for the scope of the project.

Reviewer 2:
The resources for this project are sufficient, according to the reviewer.

Reviewer 3:
The reviewer noted that the project has sufficient funding and resources to successfully complete the milestones.

Reviewer 4:
Although no financial data were reported, the reviewer assumed that funding is sufficient.

Presentation Number: bat282
Presentation Title: Development of High-Energy Lithium-Sulfur Batteries
Principal Investigator: Jun Liu (Pacific Northwest National Laboratory)

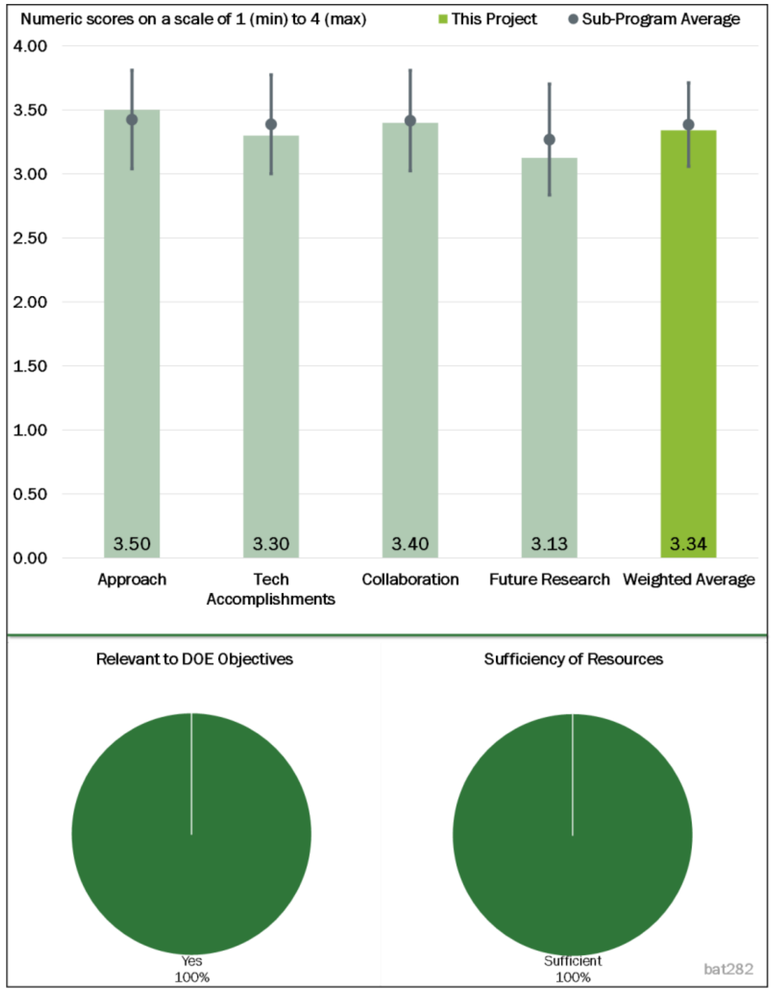

Figure 2-24 - Presentation Number: bat282 Presentation Title: Development of High-Energy Lithium-Sulfur Batteries Principal Investigator: Jun Liu (Pacific Northwest National Laboratory)

Presenter

Dongping Lu, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the PNNL team has done excellent work in studying high-energy Li-sulfur batteries. The team unveiled the effects of electrode porosity control on cell energy, sulfur utilization, electrolyte-sulfur ratio and cell-cycling life. The progress advanced the fundamental understanding of electrolyte-additive degradation mechanism in Li-sulfur batteries. The study on sulfur cathodes, by completely decoupling the interferences from lithium anodes, is innovative. The reviewer remarked that the project has made remarkable progress in addressing the technical barriers.

Reviewer 2:

The reviewer praised the good approaches for overcoming barriers of Li-sulfur batteries, including high sulfur loading, Li-anode degradation, and lithium nitrate ($LiNO_3$) depletion. The strategies seem very well designed and are feasible to the reviewer.

Reviewer 3:

According to the reviewer, the development of high-loading sulfur cathodes is a critical step for advancing Li-sulfur battery technology. The additive/binder modification by PNNL is effective and produced good results in improving the sulfur utilization ratio, thereby improving the output capacity of the cathode.

Reviewer 4:

The reviewer stated that the approach of the project is well-structured and focused on some of the key problems of Li-sulfur systems.

Reviewer 5:
The approach seemed fine to the reviewer, who wanted to see the team explain and identify some fundamental interactions that may lead to further improvements. Li-sulfur has some pretty complicated chemistry going on.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that the PNNL team has demonstrated several significant technical accomplishments and progress in the overall project. The project is in good shape in terms of milestones.

Reviewer 2:
According to the reviewer, the project is contributing to overcoming important barriers of Li-sulfur batteries, including high sulfur loading, low electrolyte/sulfur (E/S) ratio, and $LiNO_3$ problems. While contributions have been made to solving these problems, work remains to done on performance issues, such as cycle life and E/S ratio that are still not very good. The author did not report much on electrolytes for Li-sulfur batteries, which is very important.

Reviewer 3:
The reviewer stated that the project team demonstrated solid accomplishments on both the cathode and separator, which is excellent. Increasing porosity is a rather trivial improvement but a necessary step. The reviewer suggested that the team identify the exact mechanism besides increased specific area that leads to cathode improvement. The reviewer posited that the mechanism may involve higher order polysulfide chains and rings maybe filtered by pores.

Reviewer 4:
The reviewer indicated that the group has identified several degradation and performance issue effects in the sulfur cathode, which contributed to the deciphering of degradation mechanisms on these surface. However, several of these efforts seem to be stand-alone projects; e.g., a combination of electrode porosity structuring with electrolyte wetting additives could achieve better performance results and provide new insights on degradation effects at the electrode level.

Reviewer 5:
The reviewer said that the project developed high sulfur-loading cathodes that showed good capacity and cycling stability. The only concern the reviewer had is the bulky cell format. A more practical cell format will need to be developed or proposed in the program, and eventually, a kWh/kg cell should be presented as one of the final performance parameters.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that the team has been collaborating with BNL, University of Wisconsin at Milwaukee, and General Motors (GM). The collaboration is very productive.

Reviewer 2:
The reviewer indicated that the project has a very good team and good collaborations.

Reviewer 3:
The reviewer commented that the team at PNNL seems reasonably well integrated into the research network; maybe one or two additional partner building up cells with these technologies should be added. Industry partners could contribute to define the energy and performance targets at the cell level.

Reviewer 4:

The reviewer remarked that good collaboration across the teams was demonstrated on this project. For the best result, however, a separator team will help the project very positively.

Reviewer 5:

The reviewer wanted to have seen more involvement from GM. The team should be running multiple samples and demonstrating statistically significant experimental results with error bars. It looked to the reviewer like the team applied some pretty standard electrochemical energy storage (EES) measurements for some battery. The reviewer saw an outlier point in the figure on Slide 15. The reviewer would like to have seen a little more from the industrial collaborators.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted that the proposed future work is well planned. The team will focus on several key tasks, such as new cathode additives, electrode preparation methods, rational electrode architectures to enable high sulfur utilization (greater than 1,100 milliampere-hours/gram [mAh/g]) under conditions of high loading (more than 6 milligrams/square centimeter [mg/cm$^{2]}$), and dense electrodes (more than 1 gram/cubic centimeter [g/cc]). The proposed roadmap is very thoughtful and makes sense.

Reviewer 2:

The reviewer noted that the Overview Slide for the project indicates that the project ends in September 2018, but the Future Work Slide shows 2018-19. It was unclear to the reviewer if the project is ending. The Future Work slide seems generally good, but the author could place more emphasis on the electrolyte.

Reviewer 3:

In general, the proposed future work sounded reasonable to the reviewer; however, the project could benefit from a stronger combination of results and approaches towards an optimized cathode architecture that could provide interfacial stability at the electrode level. The targets of the project could be also defined on the cell level rather than the materials level to increase applicability.

Reviewer 4:

The reviewer opined that good future work was proposed only to satisfy the original work plan and objectives. A more practical energy-density target, using a kWh/kg-cell, should be included as one of the project goals.

Reviewer 5:

The reviewer agreed with trying to understand the fundamentals. Again, the chemistry is significantly more difficult that traditional Li-ion chemistry. The reviewer would like to have seen the PI identify some fundamental interactions that could lead to improvements. The additive that leads to increased porosity is okay, but an additivity that influences the chemistry is more interesting and useful to the community. The reviewer also suggested that the University of Wisconsin look at what electrolytes may improve performance. There was no mention of the electrolyte used. The reviewer also wanted to see GM running more than one sample. Also, the reviewer asked the team to add error bars to the experimental data. This is extremely important for conveying the significance of new data.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said yes, as the project does support overall DOE objectives because Li-sulfur is a high priority.

Reviewer 2:

According to the reviewer, removing the barriers of low practical energy density, shuttle effect, low rate capability, and limited cycling life is critical for commercialization of Li-sulfur batteries and highly relevant to the VTO goal.

Reviewer 3:

The reviewer responded affirmatively that Li-sulfur cells are a potential new technology for electric transportation and/or energy storage.

Reviewer 4:

Research and development on high energy-density Li-sulfur battery technology supports overall DOE objectives.

Reviewer 5:

The reviewer stated that there was excellent relevance.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the team has fully used the resources at PNNL, BNL, University of Wisconsin at Milwaukee, and GM through collaboration.

Reviewer 2:

The reviewed remarked that the current resources are sufficient to achieve the project goals.

Reviewer 3:

According to the reviewer, current resources for this project are sufficient to achieve the stated project milestones.

Reviewer 4:

The reviewer indicated that the resources are sufficient.

Reviewer 5:

Resources seemed fine to the reviewer, who suggested requiring GM to run more samples using their resources.

Presentation Number: bat293
Presentation Title: A Closed-Loop Process for End-of-Life Electric Vehicle Lithium-Ion Batteries
Principal Investigator: Yan Wang (WPI)

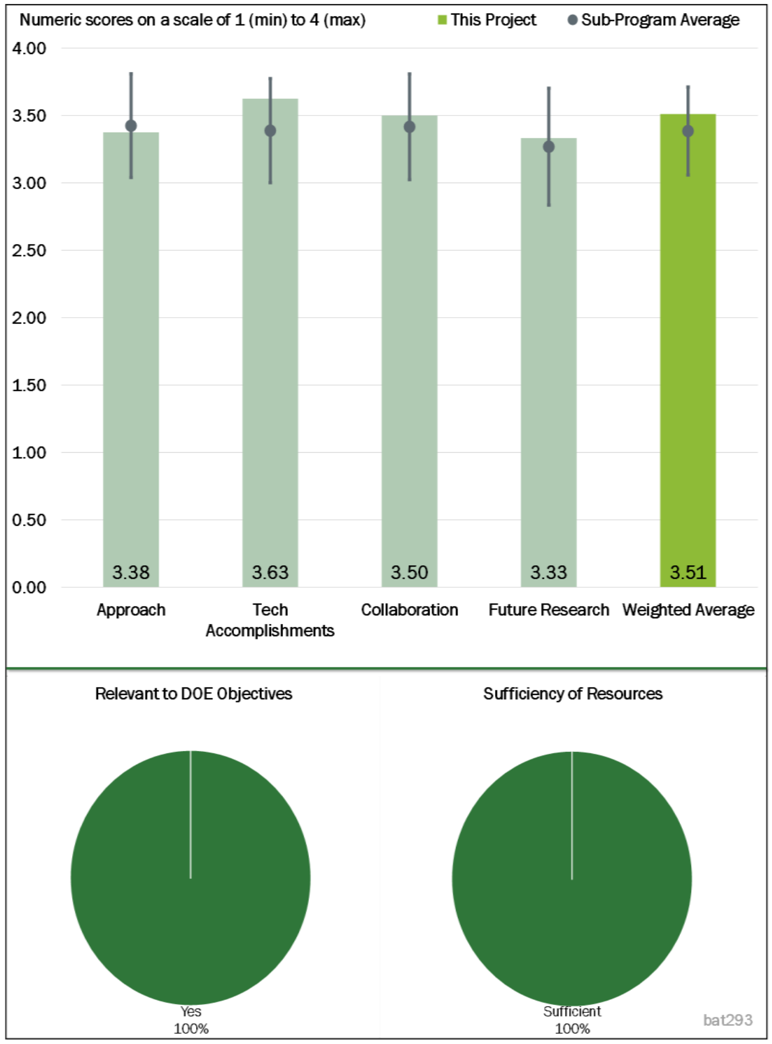

Figure 2-25 - Presentation Number: bat293 Presentation Title: A Closed-Loop Process for End-of-Life Electric Vehicle Lithium-Ion Batteries Principal Investigator: Yan Wang (WPI)

Presenter

Yan Wang, WPI

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer pronounced the approach to be great, and stated that there was a well-organized plan. The reviewer thought that the idea of turning everything into NMC (111) is a great one. The reviewer was impressed.

Reviewer 2:

The reviewer pointed out that recovering more than 90% of materials from Li-ion batteries has not been achieved in other processes; also, shredding is more efficient than burning. However, more information is required as to the quality of the materials. The reviewer asked what tests have been performed on the final products. The opinion of the reviewer was that more electrochemical testing and cost-effective studies are required to define the economic feasibility of the project.

Reviewer 3:

The reviewer would have liked some discussion on how the technology would be commercially viable as electrodes become better and better and cells last longer.

Reviewer 4:

The reviewer found the approach to be okay, but the target sort of moved over the course of the program. In retrospect, the program should have addressed the robustness of the process to changes in feed stream or changes in the Ni ratio in the resulting precursors. The precursors critical to quality characteristics were not clearly stated and may not have been thoroughly addressed. The reviewer commented that the impact of cell SOH and robustness to commingling cathode chemistries/surface-treated cathodes or even variations from suppliers should have been addressed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
Their accomplishments are terrific, according to the reviewer.

Reviewer 2:
With the limitations of academic R&D facilities and access to supplier information and requirements, the reviewer noted that the program accomplishments should be recognized.

Reviewer 3:
The reviewer observed that most of the items to be developed have been finished on time. Scaling up to commercialization level could be improved, following the indicators of the pilot plant (operational in summer 2018).

Reviewer 4:
The reviewer thought that there needs to be more investigation of cells to avoid hero cell syndrome.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer reported that the team has an impressive list of collaborators, including all three U.S. carmakers.

Reviewer 2:
The reviewer noted that several private companies contribute with samples of batteries, and the team has a partnership with one national laboratory. This collaboration and partners are present throughout the project so work is being performed under collaborations. The team has several sources of end-of-life EV batteries and specialized centers to perform tests.

Reviewer 3:
The reviewer commented that there was a good selection of teams, but the reviewer was not sure about the total interactions as some appear stronger than others.

Reviewer 4:
The reviewer pointed out that collaboration and coordination were better than average, but strong electrode active material suppliers were lacking.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that all of the important goals are in their plans. There were no specific ideas presented for how the team will overcome whatever challenges remain.

Reviewer 2:
The reviewer observed that diagrams show a plan based on the results obtained earlier. There are no alternative pathways that could be followed now that the project has ended.

Reviewer 3:
The reviewer opined that there needed to be a discussion of viability of technology as materials improve and cells last longer. Also, there was a need to evaluate the introduction of higher Ni content and other anodes.

Reviewer 4:
The reviewer stated that the project has ended.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer found the project to be tremendously important for the long-term viability of Li-battery technology.

Reviewer 2:
The reviewed stated that this project supports overall DOE goals. The fabrication of commercial cells from recycled materials could reduce costs and mitigate environmental damage of end-of-life EV batteries.

Reviewer 3:
Reducing and recycling Co is a DOE priority, according to the reviewer.

Reviewer 4:
The reviewer remarked that recovering Co imports is relevant to vehicle electrification, and recovery/recycling should be evaluated. The reviewer said that the project would be more relevant with a discussion of harvesting the active materials, dealing with the recycling process waste streams, and the potential for process intensification.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said resources are okay.

Reviewer 2:
Resources looked fine to the reviewer.

Reviewer 3:
The reviewer noted that milestones were met on schedule and budget.

Reviewer 4:
The reviewer found the resources for the project to be sufficient. Additional costs had not been reported. Due to tasks that are sequential, more resources do not mean that the milestones would have been achieved in less time. The manufacture of large batteries from recycled material demands the progressive fulfillment of scaling.

Presentation Number: bat296
Presentation Title: Development and Validation of a Simulation Tool to Predict the Combined Structural, Electrical, Electrochemical, and Thermal Responses of Automotive Batteries
Principal Investigator: Chulheung Bae (Ford)

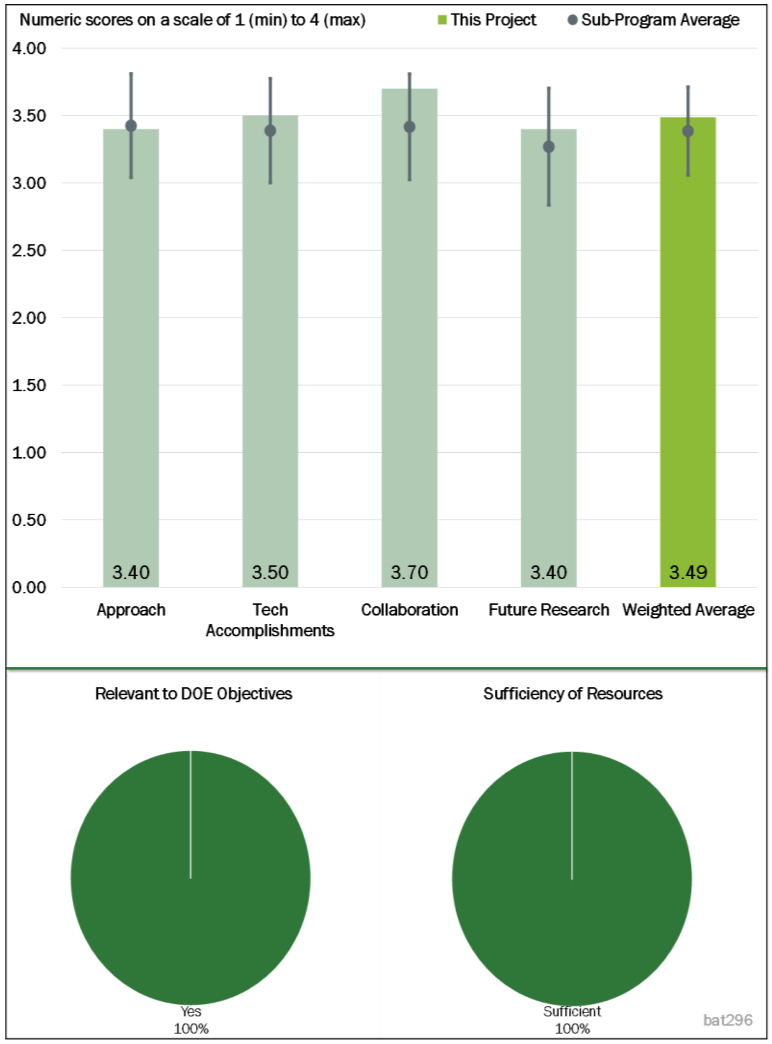

Figure 2-26 - Presentation Number: bat296 Presentation Title: Development and Validation of a Simulation Tool to Predict the Combined Structural, Electrical, Electrochemical, and Thermal Responses of Automotive Batteries Principal Investigator: Chulheung Bae (Ford)

Presenter
Chulheung Bae, Ford

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer indicated that this is a good start to the challenges of mechanical-abuse modeling of Li-ion batteries. The tasks are manageable and will add up to a potentially useful tool for the simulation of mechanical failures.

Reviewer 2:
The reviewer noted that the PI’s team has addressed most raised batteries, including the reduction of development cost and the improvement in the abuse tolerance. The project is well designed and feasible.

Reviewer 3:
The reviewer offered that researchers addressed the technical barrier very well with the developed simulation tool. Long simulation time is one of the barriers in battery simulation and the method developed will help to reduce the simulation time, keeping the accuracy.

Reviewer 4:
This project aims to provide electrochemical properties, such as ionic diffusivity, and conductivity as input data for multiphysics simulation tool developed in another project. In addition, a correlation between electrode thickness and SOC was achieved in initial cycles with slow charging. The technical barriers are addressed clearly.

Reviewer 5:

The approach seemed fine to the reviewer, who suggested using a combined thick- and solid-shell approach. The thick shell could be used for the extremely thin layers and solid elements for the materials with larger thickness. Treating everything as a single thick shell means that separation of the layers cannot be considered. This seems like a critical aspect because not all layers are perfectly adhered to each other. The reviewer would like to have seen more experimental results as it looks as if the team ran only three trials for each loading. The reviewer opined that this is a pretty straightforward test on the Angstrom machine. The reviewer would like to have seen at least 16 trials.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

According to the reviewer, the methodical development used in the technical accomplishments is well defined with define, develop, validate, and calibrate approach.

Reviewer 2:

The reviewer found the technical accomplishments and progress towards overall project to be excellent. The layered solid-element solver was further developed and calibrated with various materials models. Electromagnetic (EM) and thermal models were developed and calibrated. A new solver and an α-version multiphysics model were developed and verified with empirical data from these tests.

Reviewer 3:

The reviewer said that the accomplishments were good. It seemed to the reviewer the team has a working model that runs in a reasonable amount of wall time.

Reviewer 4:

According to the timing given in the poster, the reviewer remarked that the project has been successfully meeting its milestones with the delivery of the alpha version of the model.

Reviewer 5:

The reviewer reported that that most barriers have been effectively solved, the layered solid-element solver was developed, EM and thermal models were developed and calibrated, and a multi-physics model was developed and verified with empirical data from the following tests. However, the reviewer had two questions. In the development of the layered solid solver, the anodes and cathodes are represented by the same model, MAT-63. However, the physical and electrochemical properties for the anode and cathode may vary a lot. The reviewer asked if it is possible to develop different models for different materials. For the model to evaluate the performance of layered solid elements in EM and thermal solvers, the reviewer wanted to know if the cell deformation of the internal short-circuited cells plays an important role and should be considered. In Slide 21, the reviewer could not find a clear difference between the standard and layered solid elements and asked for a detailed explanation.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found to work to be very well coordinated with DOE national laboratories for fundamental research aspects and coupled with software developer to implement the software tool necessary to carry out the project.

Reviewer 2:

The reviewer remarked that this project is a very good collaboration between industry and the national laboratories on a problem relevant to the development of battery electric vehicles.

Reviewer 3:
The reviewer noted that both ORNL and LS-DYNA participate in the project, and are well coordinated.

Reviewer 4:
The reviewer commented that the partners participate and are well coordinated.

Reviewer 5:
Collaboration seemed fine to the reviewer, who wanted the team to seek collaboration with a DOE high-performance computing (HPC) center. The mesh count could be higher. LS-DYNA scales extremely well across processors. The team should try to keep the cell count upwards of a million cells and then run across multiple processors on the HPC system. The reviewer had several suggestions: asking Ford to speed up their testing method, conducting more experimental trials, looking into what is going on with boron nitride, and putting down a poly(tetrafluoroethylene) (PTFE) sheet and carrying on if sticking is to be avoided.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted well-thought out plans for future research. The addition of a durability assessment certainly benefits the overall development process.

Reviewer 2:
The reviewer stated that the proposed future research, including milestones and risk management, is logical.

Reviewer 3:
The reviewer supported the new experimental testing facility and the impact-based testing. The reviewer also suggested multiple pack testing. The reviewer noted that in the multipack scenario, some of the pack see a shear failure while others see a tension-tearing failure. The multi-stack configuration should be modeled to predict both of these failures.

Reviewer 4:
The reviewer commented that the cell testing data are very interesting, but in a real-world situation, the cells will be in a module configuration and may not experience mechanical abuse in the same way. The next phase of the project should emphasize module level testing/modeling.

Reviewer 5:
The reviewer reported that the PI’s team has proposed clear future research goals, which are testing the beta-version model validation and high-speed impact. These tests are effective to realize the project target, which is to predict the combined structural, electrical, electrochemical, and thermal responses of batteries. However, the overcharge issue has not been mentioned in the report.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that the team has met performance objectives, addressed barriers, there are well-defined partners for collaboration, and all deliverables in the matrix have been completed on time.

Reviewer 2:
According to the reviewer, this project supports the overall DOE objectives. Developing a simulation tool to predict the combined structural, electrical, electrochemical, and thermal (EET) responses of automotive batteries could improve their performance and reduce the cost of the vehicles.

Reviewer 3:
The reviewer found the relevance to be excellent.

Reviewer 4:
The reviewer affirmed that this project should help with the development of safe electric vehicles.

Reviewer 5:
The reviewer commented that this project supports the overall DOE objectives because the prediction of battery safety is important and necessary for the development of high-energy and low-cost batteries.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked that the resources seem appropriate for this program. More funding may be needed for module-level abuse testing.

Reviewer 2:
The reviewer stated that the research team has sufficient funding, human resources, and equipment to complete the project.

Reviewer 3:
The reviewer said that the partners were chosen for understanding the fundamentals as was the software developer for simulation tools that help to achieve the timely deliverables.

Reviewer 4:
Resources seemed good to the reviewer, who suggested that the team should be using a HPC system. The reviewer commended the attempt to find a new experimental test facility that has better throughput.

Reviewer 5:
The reviewer commented that the resources are sufficient to achieve the stated milestones in a timely fashion. A proper supplier to run material analyses for the beta-version, model-validation tests is very necessary.

Presentation Number: bat298
Presentation Title: Efficient Simulation and Abuse Modeling of Mechanical-Electrochemical-Thermal Phenomena in Lithium-Ion Batteries
Principal Investigator: Shriram Santhanagopalan (National Renewable Energy Laboratory)

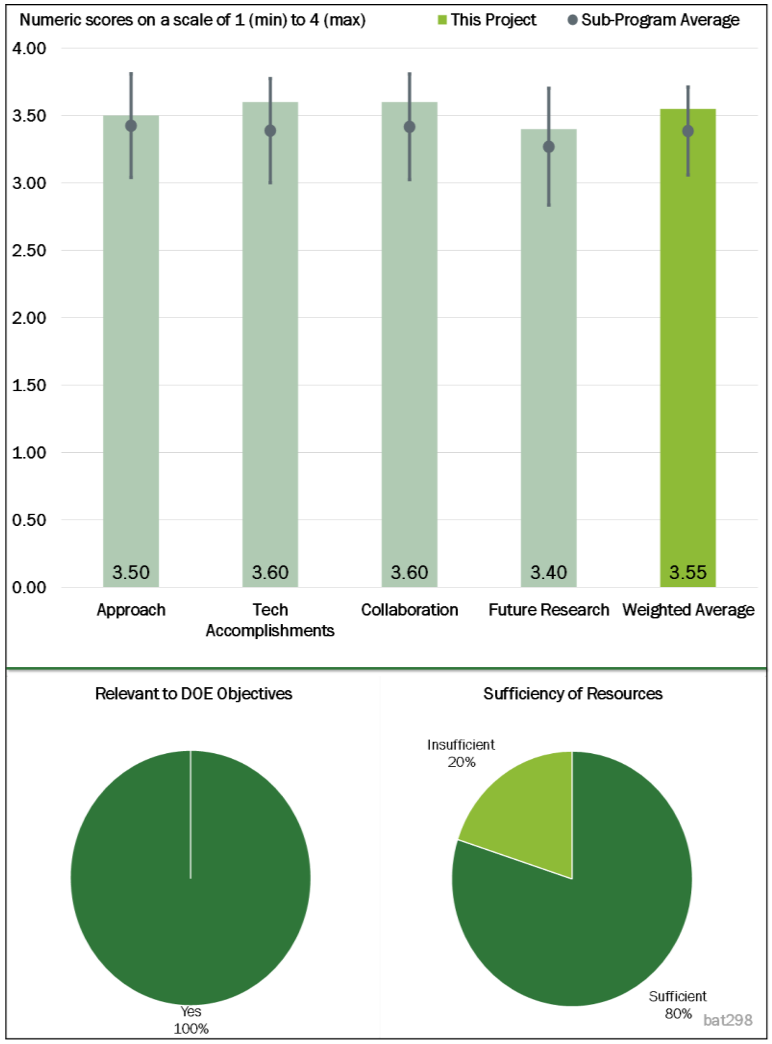

Figure 2-27 -Presentation Number: bat298 Presentation Title: Efficient Simulation and Abuse Modeling of Mechanical-Electrochemical-Thermal Phenomena in Lithium-Ion Batteries Principal Investigator: Shriram Santhanagopalan (National Renewable Energy Laboratory)

Presenter

Shriram Santhanagopalan, National Renewable Energy Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that this project has a well thought-out set of steps and tasks to combine the electrochemical modeling with mechanical-abuse modeling. The layout of the milestones and collaboration between the national laboratories should also contribute to the success of the project.

Reviewer 2:

Gap between the modeling tools and cell design is very well captured in this development tool, according to the reviewer. Collaborating with the right partners in both academia and industry expedites the development process and addresses the technical barriers.

Reviewer 3:

The reviewer commented that the project is well-designed. This is a good approach to develop effective simulation tools for practical assessment of battery safety and close the gap between materials R&D and modeling tools. The failure mechanism is also investigated in this project and guides the battery design.

Reviewer 4:

The approach seemed okay, but the reviewer was not sure what the PI meant by “efficient model.” The reviewer had some concern with the strain-rate and heat-transfer measurements. The reviewer noticed that the team has an ANSYS model image and LS- DYNA images. The images should be able to solve everything, including heat transfer (HT) in LS-DYNA.

Reviewer 5:

The reviewer commented that, having reviewed last year, the work is outstanding in nature with a few top-class people in the world. The reviewer felt that project may be a little behind schedule due to previous budget issues; the team should be given the opportunity to complete the project, and if the budget is available, the project should be allowed to continue on extension/proposed research for the next few years.

Regarding the reviewer's concern about beta-version commercialization and expected outcome, the presenters mentioned that one of the automobile companies has licensed the technology. Regarding the reviewer's concern about $80/kWh, the presenters think it will be possible with a thick electrode. Milestone 2.4 has been delayed. Argonne provided the experimental matrix data source. The reviewer suggested that in the design of experiments, the Taguchi fractional factorial design, the project team needs to decide which factors (porosity, thickness, diffusivity) and levels of experiments need to be repeated to reduce time.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

With very good understanding of the underlying issues and collaborating with the right technical partners, the reviewer noted that the researchers have accomplished the technical challenges. Cell testing and validating with the software tools is a nice development approach.

Reviewer 2:

According to the reviewer, some accomplishments have been demonstrated with publications in journals.

Reviewer 3:

The reviewer commented that the project appears to be making good progress towards the goals. The model-to-experimental data comparison for the computational efficiency portion of the project is impressive. The reviewer stated that it is harder to characterize the effectiveness of the Task 2 work because it is more difficult to compare experimental data to modeling data in the case of the mechanical modeling.

Reviewer 4:

The reviewer asserted that excellent progress has been made in the project. The project calibrated a Newman model to show the agreement of a macro-homogeneous model against the entire Cell Analysis, Modeling, and Prototyping (CAMP) Facility library. The mechanical-electrochemical-thermal model was developed for mechanical abuse simulation. All of these are good for mechanical characterization of cell components and the investigation of the complex failure mechanism. However, the identification and simulation in the project are based on Gr/NCM532. The reviewer wanted to know if the model is suitable for other battery systems, and how does it give a guide to designing new battery materials.

Reviewer 5:

The reviewer commented that, having reviewed last year, the work is outstanding in nature with a few top-class people in the world. The reviewer believed that the project may be a little behind schedule due to previous budget issues; the team should be given the opportunity to complete the project, and if the budget is available, the project should be allowed to continue on extension/proposed research for the next few years.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that the collaboration of academic researchers, industry partners, and DOE national laboratories has strengthened the development process. Integrating the development with software vendors adds significant value to the user community.

Reviewer 2:

The reviewer noted that this project contains many collaborators and partners. All the partners participate and contribute to the work of the project. The whole team is well coordinated and has a clear-cut division of labor.

Reviewer 3:

The collaboration seemed good to the reviewer, who suggested better collaboration and discussion about the high strain-rate data and discussions with the current collaborators at Ohio State University and George Mason University.

Reviewer 4:

It was clear to the reviewer there is good collaboration and coordination among the many laboratories on this project. The reviewer thought that the project could benefit from some industry partners to help focus the deliverables on the coupled mechanical modeling in Task 2.

Reviewer 5:

The reviewer commented that, having reviewed last year, the work is outstanding in nature with a few top-class people in the world. The reviewer perceived that project may be a little behind schedule due to previous budget issues; the team should be given the opportunity to complete the project, and if the budget is available, the project should be allowed to continue on extension/proposed research for the next few years.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that fracture of electrode composite is a complex problem and requires a very high level of understanding from many aspects. Researchers have proposed a well-thought out plan to capture these issues. Overall, the proposed future research is very good.

Reviewer 2:

In terms of future work, the reviewer commented that the project plan to use dynamic loading tests to characterize failure at higher strain rates is more reasonable than static testing.

Reviewer 3:

The reviewer said that if the budget is available, the project should be allowed to continue on extension/proposed research for the next few years on fracture experiments.

Reviewer 4:

The reviewer remarked that the progress on the project is impressive so far, with work done towards understanding the fundamentals of the mechanical abuse. It was harder for the reviewer to see how this can be used in a practical situation. Part of the focus of the future work should be on the applicability of the work on the design of battery packs.

Reviewer 5:

Future work seemed okay to this reviewer, who suggested that the PI get a little more organized because of the several important tasks going on here. The reviewer saw heat-transfer and strain-rate effects as the two important topics for future work. There probably needs to be some better discussion among collaborators. The heat-transfer model needs a little more work. It looks like there is a boundary-condition issue based on the plot provided on Slide 23. The reviewer also proposed that the PI consider interface conductance and assumed that the PI is modeling each of the layers as perfect conductors. The PI also needs to be careful with thermal-conductivity values used in the model as the reviewer wanted to know the source of these values, which should be temperature dependent. The reviewer asked about endo- and exothermic reactions contributing to heat transfer and whether these effects have been considered or whether the PI has been looking at thermal conductivity from the outside conducting through the stack. The reviewer added that the PI should set up some quick experiments to determine the thermal conductivity of each of the materials by themselves and then the bilayer conduction.

Other suggestions from the reviewer included taking a good look at, and holding discussions with, the collaborators about the strain-rate measurements shown on Slide 18. The reviewer expected that as the strain rate increases, the strain-to-failure (displacement) rate would decrease, and the reviewer also suggested that the strength-out rate would increase. If the PI is confident the results are correct, then there might be a contact effect that is causing increased displacement with increased strain rate. The reviewer recommended simulating this interaction with LS-DYNA to confirm this claim. The PI should also seek a discussion with some experts at SNL about strain-rate effects. There are researchers at SNL and Lawrence Livermore National Laboratory who do these strain rate effects (Split-Hopkins) measurements everyday. Also, the reviewer stressed looking into their technical reports for strain-rate experimental data as they have run a bunch of materials already that might be able to be used directly in the LS-DYNA models.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer observed that the project standardizes identification of the model parameters, increases computational efficiency, extends the models to include mechanical failure of cells and packaging components, and closes gaps between materials R&D and computer-aided engineering of batteries (CAEBAT) modeling tools. When the battery community uses these tools, the number and duration of battery test and module/pack costs can be significantly reduced. Thus, the project supports the overall DOE objectives.

Reviewer 2:

The reviewer responded affirmatively that this project should help with improving safety and lowering the development costs of vehicle batteries.

Reviewer 3:

The reviewer believed that DOE is trying to reduce the battery cost to $80/kWh and this kind of technically competent researchers can achieve DOE goal.

Reviewer 4:

The reviewer found the project to have great relevance.

Reviewer 5:

While the overall DOE objectives have been met and the relevance, barriers, and project plan are all good, the reviewer recommended that the researchers should consider highlighting what the main objective is.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer thought that the project should get more funding to conduct mechanical-abuse testing of cells and modules and to help with the correlation between experiments and modeling on a cell or even module level.

Reviewer 2:

According to the reviewer, the team has experienced researchers and partners and is well-equipped with the necessary instruments that could allow the team to achieve the stated milestones in a timely fashion.

Reviewer 3:

The reviewer noted that the researchers have sufficient resources available to carry the task in a timely fashion and they have also documented that very well.

Reviewer 4:

Resources seemed good to the reviewer, who suggested trying to get some advice from an engineer at SNL on strain-rate effects on materials, contact surface, etc.

Reviewer 5:

While talking with presenters, the reviewer found that the DOE budget was a little bit of an issue so the project is behind schedule. The reviewer thought that in terms of knowledge or national laboratory resources, it is not a concern.

Presentation Number: bat299
Presentation Title: Microstructure Characterization and Modeling for Improved Electrode Design
Principal Investigator: Kandler Smith (National Renewable Energy Laboratory)

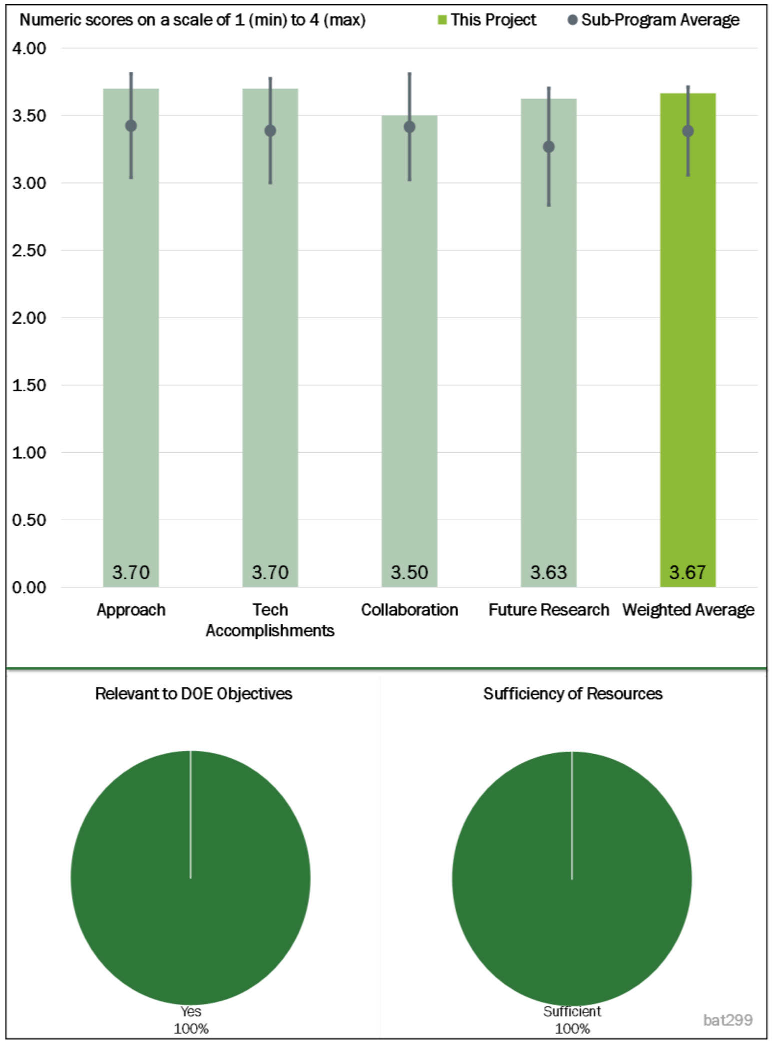

Figure 2-28 - Presentation Number: bat299 Presentation Title: Microstructure Characterization and Modeling for Improved Electrode Design Principal Investigator: Kandler Smith (National Renewable Energy Laboratory)

Presenter

Kandler Smith, National Renewable Energy Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach seemed great to the reviewer, and it looked as if the project team is getting some good information from the model.

Reviewer 2:

Overall, the reviewer remarked that this is a very interesting project addressing a gap in the currently available battery modeling tools. The approach towards the technical challenges is well thought-out and the project is showing results.

Reviewer 3:

The reviewer commented that the researchers addressed the technical barrier in microstructure characterization sufficiently. Electrode design through mesoscale modeling is well designed and feasible.

Reviewer 4:

The reviewer commented that, having reviewed last year, the work is outstanding in nature with a few top-class people in the world. The reviewer believed that project may be a little behind schedule due to previous budget issues; the team should be given the opportunity to complete the project, and if the budget is available, the project should be allowed to continue on extension/proposed research next few years.

Regarding the reviewer's concern about beta-version commercialization and expected outcome, the presenter mentioned that one of the automobile companies has licensed the technology. Regarding the reviewer's concern about \$80/kWh, the presenters think it will be possible with a thick electrode. Milestones 2.3 and 2.4 appear to be new as they were not there in 2017. Argonne provided the experimental matrix data source on Slide 15. The reviewer suggested that in the design of experiments, the Taguchi fractional factorial design, the project team needs to decide which factors (porosity, thickness, diffusivity) and levels of experiments need repeating to reduce time. In discussions with the presenter about the binder for the model on Slide 9, the reviewer learned that polyvinylidene difluoride (PDVF) and the Purdue University model were used. The reviewer recommended that be used in future presentations. The reviewer also suggested that the presenter use impedance instead of resistance with a C-rate plot although the reviewer wad told that the nature of the plot would not change. In discussing the 1C and 5C rates on Slide 12, the reviewer learned that the maximum is 12C and the presenters are aware of that. Lastly, the reviewer mentioned the team finally discussed the remaining challenges and barriers.

Reviewer 5:

The reviewer pointed out that the developed microstructure modeling and characterization well-predicted the impact of the electrode recipe and design on electrode performance at different C rates and electrode thicknesses. However, some problems need to be considered during the modeling analysis to further shrink the gaps between the modeling and practical cell design. First, because the resistance changes with increasing electrode thickness, the effects of electrode thickness on microstructural-resistance analysis and rate capability need to be considered. Second, the resistance analysis at different cycle life should be considered because the internal resistance will change during cycling. Finally, the anode side needs to be considered during the modeling or resistance analysis because the Gr electrode would probably bear the similar microstructural problems.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer pronounced the accomplishments to be great.

Reviewer 2:

The reviewer stated that there are still there are many challenges in mesoscale modeling of electrodes. The authors attempted to address all the challenges through imaging, simulation, and homogenization to achieve desired performance indicators.

Reviewer 3:

The reviewer found the technical accomplishments for this project to be very interesting and looked forward to seeing the results of the final phase of the project.

Reviewer 4:

The developed microstructure modeling and characterization has made great progress toward overcoming the barriers and conforming to the schedule, according to the reviewer. The effects of the electrode recipe and morphologies (e.g., electrode thickness, tortuosity due to C-binder, porosities, particle size or shape) on electrode performance have been well modeled and validated by experiments. However, for better predicting or instructing the industrial cell design, more efforts need to be made, like fulfilling the model by considering more comprehensive factors (e.g., cycling life, temperature, etc.) and validating from more battery-cycling experiments (e.g. long-term cycling, different loading, and C rate).

Reviewer 5:

The reviewer commented that, having reviewed last year, the work is outstanding in nature with a few top-class people in the world. The reviewer believed that project may be little behind schedule due to previous budget issues; the team should be given the opportunity to complete the project, and if the budget is available, the project should be allowed to continue on extension/proposed research next few years.

Regarding the reviewer’s concern about beta-version commercialization and expected outcome, the presenter mentioned that one of the automobile companies has licensed the technology. Regarding the reviewer’s concern about $80/kWh, the presenters think it will be possible with a thick electrode. Milestones 2.3 and 2.4 appear to be new as they were not there in 2017. Argonne provided the experimental matrix data source on

Slide 15. The reviewer suggested that in the design of experiments, the Taguchi fractional factorial design, the project team needs to decide which factors (porosity, thickness, diffusivity) and levels of experiments need to be repeated to reduce time. In discussions with the presenter about the binder for the model on Slide 9, the reviewer learned that PDVF and the Purdue University model were used. The reviewer recommended using that in future presentations. The reviewer also suggested that the presenter use impedance instead of resistance with a C-rate plot although the reviewer wad told that the nature of the plot would not change. In discussing the 1C and 5C rates on Slide 12, the reviewer learned that the maximum is 12C and the presenters are aware of that. Lastly, the reviewer discussed the remaining challenges and barriers.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
It looked to the reviewer as if the collaborators are working well together.

Reviewer 2:
The reviewer stated that the collaboration was outstanding, and Kander is handling it very well.

Reviewer 3:
The reviewer commented that there were good collaborations with various partners from national laboratories to universities. All the partners with their distinct advantages participate and are well coordinated to contribute to the progress of the project.

Reviewer 4:
The reviewer remarked that the project was well coordinated among DOE national laboratories and academia. The addition of an industry partner will help to identify the real time and practical risks.

Reviewer 5:
The reviewer stated that this project and the other related projects are successfully working within the national laboratory and university system. The reviewer thought that the project would benefit from industry partners to help with the practical application of the work being done.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that design inputs, validation, and performance against multiple design are logical steps considering the technical barriers and effective realization of the technology. Particle approach, electrode mechanics, and application of design studies for new materials address alternating development paths and attempts to mitigate risks.

Reviewer 2:
The reviewer suggested looking at temperature-dependent materials models and how they might be implemented. Other ideas for consideration are including advection of the electrolyte in addition to diffusion, and validating conductivity predictions. The reviewer was not sure if changes in conductivity as a function of temperature had been considered. The localized conductivity will decrease with increase in temperature.

Reviewer 3:
The reviewed viewed the future work as exactly right for this project. One big challenge will be to obtain the 3-D views of the carbon + binder domain (CDB). This would be particularly helpful in the design of fast-charge anodes for high energy-density EV cells.

Reviewer 4:
The reviewer stated that if the budget is available, the project should be allowed to continue on extension/proposed research for the next few years.

Reviewer 5:
The reviewer said not applicable.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
Through the systematic microstructure modeling and characterization, the reviewer noted that some key factors that affect the electrode performance can be screened out and some fundamental understanding of the electrode design could be provided. These factors can be used to guide practical electrode fabrication for further improving battery performances or enhancing the energy densities. Therefore, this project supports the overall DOE objectives. The reviewer said that the project captures the overall DOE objectives. Microstructure imaging of carbon-binder domain (CBD) at different cycles to capture the randomized particle sizes will be helpful for stochastic evaluation.

Reviewer 2:
The reviewer affirmatively found the project to be very relevant. This project turned out really well, and the reviewer thought that others can really build off these findings.

Reviewer 3:
The reviewer responded yes, and noted that battery-cost reduction to make EVs practical and setting a goal of $80/kWh are right in target.

Reviewer 4:
The reviewer stated that the project captured the overall DOE objectives.

Reviewer 5:
The reviewer affirmatively commented that this and the other CAEBAT modeling projects do support the DOE goals to reduce the cost of battery development. The reviewer noted that these projects would greatly benefit from an industry partner to make sure they can be used as intended by Li-ion battery cell designers to lower the development costs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The resources seemed sufficient to the reviewer to support the current level of research.

Reviewer 2:
Resources are sufficient for this project, according to the reviewer.

Reviewer 3:
The reviewer said the resources were good.

Reviewer 4:
The reviewer thought that the resources are appropriate for this program, but more resources may be needed for the 3-D imaging of the CBD.

Reviewer 5:

The reviewer felt that project may be a little behind schedule due to previous budget issues; the team should be given the opportunity to complete the project, and if the budget is available, the project should be allowed to continue on extension/proposed research for the next few years.

Presentation Number: bat300
Presentation Title: Enhancement and Deployment of VIBE, the Open Architecture Software (OAS) Environment
Principal Investigator: Srikanth Allu (Oak Ridge National Laboratory)

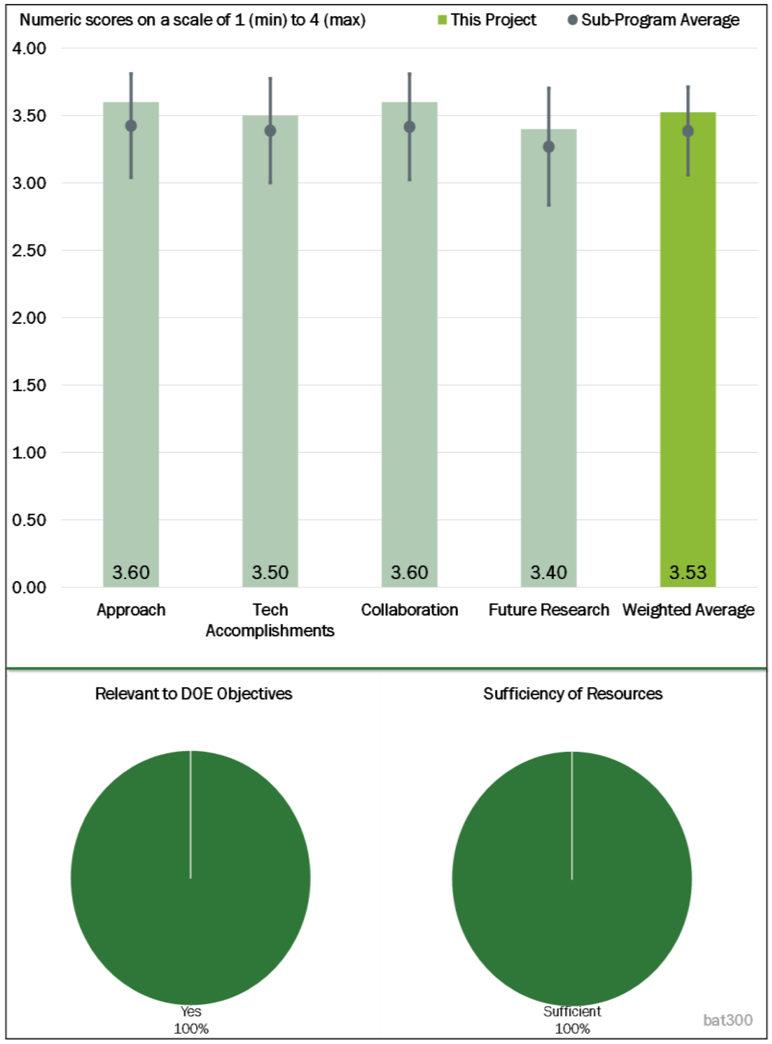

Figure 2-29 - Presentation Number: bat300 Presentation Title: Enhancement and Deployment of VIBE, the Open Architecture Software (OAS) Environment Principal Investigator: Srikanth Allu (Oak Ridge National Laboratory)

Presenter

Srikanth Allu, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that this project helps design a tool to allow researchers to explore battery response under both normal and abusive conditions. The simulation and experimental results show us what is happening when a Li-ion battery gets a short circuit, it is helpful to design battery management systems for safe operation of large battery packs.

Reviewer 2:

The reviewer stated that the approach is excellent.

Reviewer 3:

The reviewer said that major barriers of battery energy density are addressed very well from the perspectives of physical phenomena as well as predictive simulation tools.

Reviewer 4:

Overall, the reviewer commented that this is a very interesting project that addresses a gap in the currently available battery modeling/simulation tools.

Reviewer 5:

The reviewer noted that the approach seems fine, but wanted to have seen more validation if possible.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the experimental and simulation results show us what is happing when a Li-ion battery gets a short circuit: separator failure criterion, microstructure reorganization under mechanical loading, and fragmentation of anode-current collectors.

Reviewer 2:

By developing new experiments, capturing fragmentation of anodes, and reconstructing the fragmentation problems, the reviewer stated that the technical accomplishments are augmented. Accomplishments are correlated well against the measured performed indicators.

Reviewer 3:

For section 1.4 in the poster, the reviewer noted that the demonstrated ability to predict the onset of a short from mechanical deformation was not present, so it is very difficult to determine if this statement is true or not. Most of the conclusions on Slide 10 were given without data to back up the claims.

Reviewer 4:

The reviewer reported that the PI mentioned that the project is 75% complete although the poster says 55%. The PI mentioned to the reviewer that due to budget constraints there may be a possibility of project delay.

Reviewer 5:

The reviewer wanted more validation of the model with experiments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the collaboration with national laboratories (SNL, LBNL, ANL, and National Renewable Energy Laboratory [NREL]) can not only provide some experimental results and advanced techniques to this project, but also they can help analyze whether the designed simulation method is correct or not.

Reviewer 2:

The Involvement of different DOE national laboratories adds more value to the project, according to the reviewer.

Reviewer 3:

The reviewer observed excellent collaboration, and reported having mentioned to the PI work between ORNL and the DOT that was not mentioned in reference to *Crashworthiness Models for Automotive Batteries, A Report on the Department of Energy Project 2088-A031-15 for the National Highway Traffic Safety Administration (NHTSA), an Agency of the U.S. Department of Transportation* (J. A. Turner, S. Allu, et al. 2018), which discusses fragmentation of copper anode, etc..

Reviewer 4:

Collaboration seemed good to the reviewer, who suggested trying to find a point of contact at Nissan to collaborate with in order to get more information about Leaf battery testing. That would yield potentially more data to validate against.

Reviewer 5:

The reviewer asserted that this project and the other related projects are successfully working within the national laboratory and university systems. The reviewer thought that the project would benefit from industry partners to help with the practical application of the work being done.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the project aims to develop a tool to allow researchers to explore battery response under both normal and abusive conditions. However, when the battery gets a short, lots of things will happen within a short time. Thus, it is pretty challenging to simulate what is happening on a battery short circuit. The future research plan comes up with some other methods for further study and understanding battery response.

Reviewer 2:
According to the reviewer, researchers have considered broad areas to address for future research. High-computation risk mitigation using reduced-order modeling and integration of different models to provide alternating development avenues are interesting approaches.

Reviewer 3:
The reviewer wanted to see an experimental approach included that demonstrates this model's ability to truly detect an onset of a short-based on-mechanical deformation.

Reviewer 4:
The reviewer stated that some of the remaining challenges and barriers mentioned by the PI should be allowed to continue, e.g., insufficient understanding of thermal runaway and internal shorts due to Li plating.

Reviewer 5:
The reviewer wanted more validation of the model.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer remarked that this project supports the overall DOE objectives to develop a Li-ion battery with higher energy density, which requires much more strict control on battery safety. This project uses the simulation tool to understand battery response under both normal and abusive conditions, which is helpful to design battery management systems.

Reviewer 2:
The reviewer stated that the project addresses the overall DOE objectives. Simulation gaps and underlying insufficiencies in physical phenomena are identified and addressed properly

Reviewer 3:
There is understanding of the physical phenomena for battery safety and performance, according to the reviewer.

Reviewer 4:
The reviewer found great relevance.

Reviewer 5:
The reviewer responded affirmatively and elaborated that this and the other CAEBAT modeling projects do support the DOE goals to reduce the cost of battery development. The reviewer thought that these projects would greatly benefit from an industry partner to make sure they can be used as intended by Li-ion battery cell designers to lower the development costs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the team and its collaborators have sufficient resources to go on with the research and achieve the stated milestones, including designing new experiments, advanced characterization techniques, and powerful simulation tools.

Reviewer 2:

The reviewer said that sufficient resources are available for researchers to pursue this project.

Reviewer 3:

The reviewer commented that resources are appropriate for the project.

Reviewer 4:

The reviewer stated that the overall project has the support of the best technical resources; if the budget is not a constraint, then the project can be completed on time.

Reviewer 5:

Resources seem good to the reviewer, who noted that, actually, there are a lot of people working on this project. The reviewer expected some more claims coming from this work and suggested that the PI evaluate everyone's contribution and make sure everyone is contributing who is being paid on this project.

Presentation Number: bat301
Presentation Title: Experiments and Models for the Mechanical Behavior of Battery Materials
Principal Investigator: Sergiy Kalnaus (Oak Ridge National Laboratory)

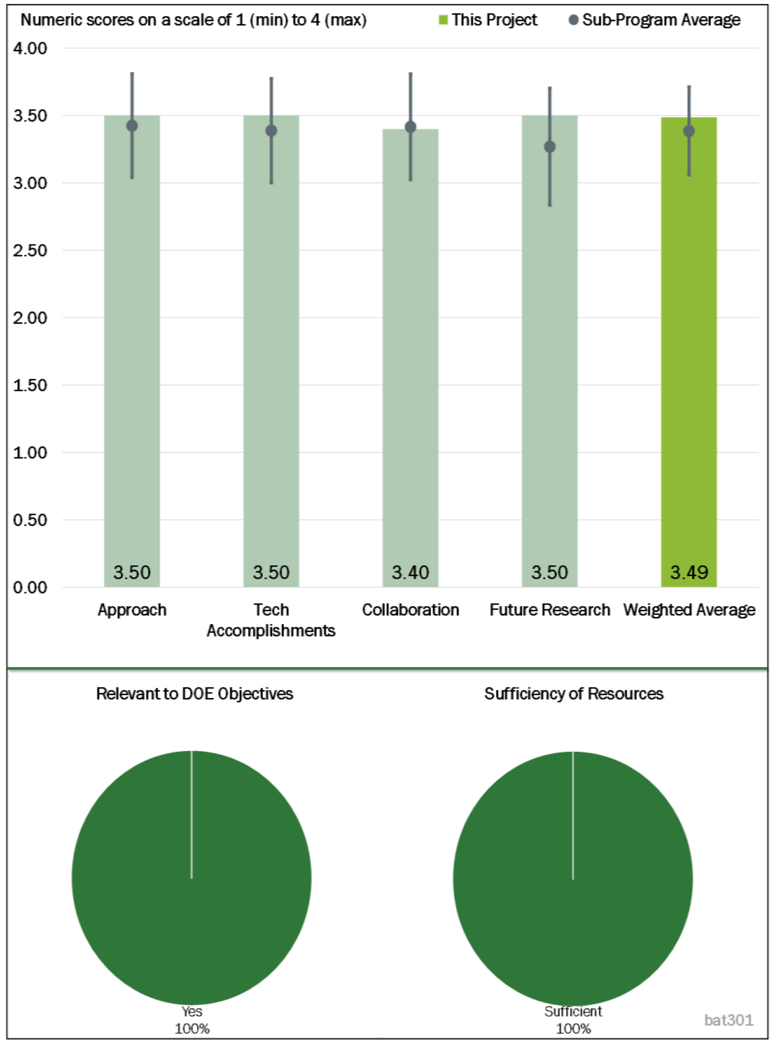

Figure 2-30 - Presentation Number: bat301 Presentation Title: Experiments and Models for the Mechanical Behavior of Battery Materials Principal Investigator: Sergiy Kalnaus (Oak Ridge National Laboratory)

Presenter

Sergiy Kalnaus, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that, generally speaking, the approach that the ORNL group has adopted is well designed and feasible. It is effective to develop mechanics models and failure criteria based on measurements of mechanical properties and other models (E-Chem, thermal). The methods that the group chose for investigation, like biaxial deformation test and X-ray tomography tests, are efficient to investigate failure criteria and address technical barriers.

Reviewer 2:

Overall, the reviewer stated that this is a very interesting project addressing a gap in the currently available battery-modeling tools. The approach towards the technical challenges is well thought-out and the results demonstrate that.

Reviewer 3:

According to the reviewer, researchers have a well-defined approach to addressing the technical barriers and relevance. Coordinating experimental and simulation work in parallel is a good plan.

Reviewer 4:

The reviewer liked the approach, and there is some good information here that others could use.

Reviewer 5:

The reviewer said that the project is feasible and well designed, and the team has addressed the technical barrier.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that mechanical properties of the cell components are being measured, and researchers have a thorough understanding of the complex behavior of each component. The project team has made an excellent effort to understand the conditions for short circuits.

Reviewer 2:

The reviewer noted that this is a very important part of the modeling work, and it would be interesting to see the effects of cell aging on the properties in this study.

Reviewer 3:

The reviewer pointed out that the digital image correlation (DIC) measurements look consistent with failure. However, the reviewer expected a strain field more like the model is showing and posited that there must be a bias in the experiment. The reviewer asked if the sphere is perfectly in the center.

The reviewer said the PI might also consider whether to add the holes into the finite element analysis simulation. This approach would allow using a shell element to model the voids and run the mesh cells upwards of 1 million cells to reach a more realistic simulation. According to the reviewer, the cracking on the current collector looks like an adhesion failure between the layers, as if the materials are actually adhering to the neighboring layer and failing when the layers relax after loading.

Reviewer 4:

The reviewer mentioned that the project is 75% complete, and it appears that a 1-year extension will help to complete it. The project is a little behind schedule on some milestones (e.g., I.5, C.3, C.4, C.5, C.6, I.6) because of budget constraints as mentioned by the PI.

Reviewer 5:

The progress of the project is generally effective, according to the reviewer. However, there is still 25% percent of the project needs to be completed so far as mesoscale simulations, deployment of virtual integrated battery environment/open architecture software (VIBE/OAS) with the integrated multiscale capability, and other milestones that have not been reached yet.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found good collaboration with DOE national laboratories. Including the CAEBAT project team helps to speed up the development process cross functionally.

Reviewer 2:

The reviewer observed excellent collaboration, and reported having mentioned to the PI work between ORNL and DOT that was not mentioned in reference to *Crashworthiness Models for Automotive Batteries, A Report on the Department of Energy Project 2088-A031-15 for the National Highway Traffic Safety Administration (NHTSA), an Agency of the U.S. Department of Transportation* (J.A. Turner, S. Allu et al. 2018), which discusses fragmentation of copper anode, etc.

Reviewer 3:

This project has good collaboration with its project team, according to the reviewer.

Reviewer 4:

The reviewer said that the collaboration was good.

Reviewer 5:
The reviewer observed that the partners in the project team are well coordinated and have made their own contribution to the overall project. However, SNL did not complete milestone C.3 on time, and the contribution of ANL is unclear.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer asserted that researchers have identified critical areas for future research both experimentally as well as simulation.

Reviewer 2:
Biaxial testing of electrodes sounded good to the reviewer.

Reviewer 3:
The reviewer stated that the future work is well thought-out. The reviewer was glad to see the effects of aged components included because the mechanical properties could change with cycling/exposure to the electrolyte.

Reviewer 4:
The reviewer noted that the PI had mentioned that proposed future research is ongoing, e.g., biaxial compression of electrodes, in situ X-ray tomography.

Reviewer 5:
According to the reviewer, the proposed future research plan has included the key points that should be accomplished in the future although more details of the plan could be given.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
This project supports the overall DOE objectives, according to the reviewer. This project has investigated the physical phenomena in batteries and proposed mechanics models and failure criteria. All of these research results are beneficial for increasing battery performance.

Reviewer 2:
The reviewer noted that this better understanding of failure of battery-electrode materials will help with battery safety.

Reviewer 3:
The reviewer commented that, overall, the project addresses the DOE objectives.

Reviewer 4:
The reviewer responded affirmatively and said that the work was relevant.

Reviewer 5:
The reviewer affirmed that this and the other CAEBAT modeling projects do support the DOE goals to reduce the cost of battery development. The reviewer thought that these projects would greatly benefit from an industry partner to make sure they can be used as intended by Li-ion battery-cell designers to lower the development costs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked that there sufficient resources have been allocated to perform the task.

Reviewer 2:

The reviewer commented that resources are appropriate for the project.

Reviewer 3:

The reviewer noted that the project is a little behind schedule at 75% complete, which the PI mentioned was mainly due to budget issues at the beginning of the fiscal year. It seemed to the reviewer that the team will be able to complete another year.

Reviewer 4:

The project has sufficiently used the resources for the project to achieve the stated milestones, although the team has not yet reached some of the milestones.

Reviewer 5:

The reviewer suggested looking at the sand models from LS-DYNA as they may help with granular modeling and validation.

Presentation Number: bat302
Presentation Title: Microstructure Imaging and Electrolyte Transport Property Measurements for Mathematical Modeling
Principal Investigator: Venkat Srinivasan (Argonne National Laboratory)

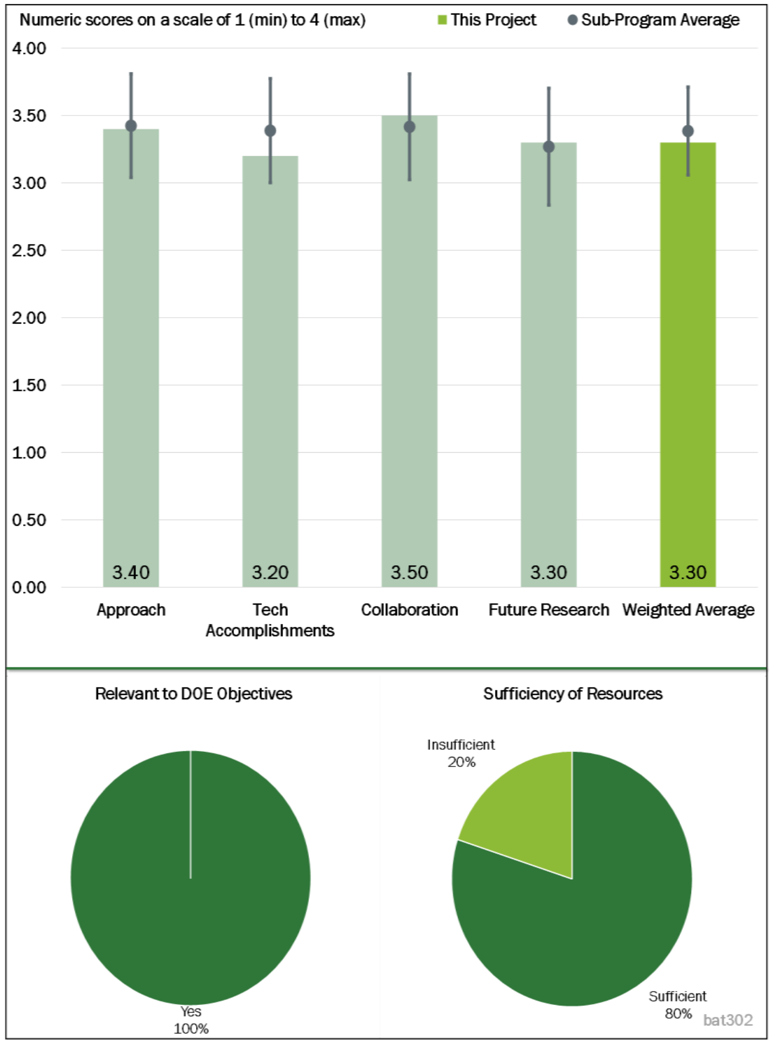

Figure 2-31 - Presentation Number: bat302 Presentation Title: Microstructure Imaging and Electrolyte Transport Property Measurements for Mathematical Modeling Principal Investigator: Venkat Srinivasan (Argonne National Laboratory)

Presenter

Venkat Srinivasan, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that this project aims to provide electrochemical properties, such as ionic diffusivity and conductivity, as input data for a multiphysics simulation tool developed in another project. In addition, a correlation between electrode thickness and SOC was achieved in initial cycles with slow charging. The project is well-designed.

Reviewer 2:

The reviewer commented that this is a very interesting project, well designed, and an important piece of information to feed into the modeling project.

Reviewer 3:

The reviewer remarked that the approach that was used is fairly effective. The collection of in-operando images using cycled electrode materials is important to support modeling results.

Reviewer 4:

The reviewer found that the researchers had made good progress in capturing the relevant images of electrodes. Overall, the reviewer found this to be a well-defined approach.

Reviewer 5:

The approach seemed okay to the reviewer, and this is a necessary task to determine the internal structure. However, the reviewer was not sure the beam-line source is the best method. There are several industrial and medical computerized tomography (CT) machines that will provide equivalent resolution. All the reconstruction algorithms have been developed. Actually, there has been extensive research on frequency-domain methods that filter and reconstruct the volumes. The reviewer was not sure that CD-adapco really has the momentum to beat many of these established methods. Something more interesting about these industrial and medical CT machines is that transient information can be captured, which means that the battery can be charged and discharged while capturing the CT information. This is commonly done to look at the fluid flow through porous media. So, the reviewer was not convinced that the beam-line source is the best option. What would be interesting would be doing a neutron-imaging technique to get a better grasp on the C formation, such as a neutron spallation experiment with the beam line. This technique is actually used to see atomic hydrogen and oxygen so there should not be a problem seeing atomic C. The reviewer pointed out that this technique has been employed to look at crack propagation in superalloys.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer stated that most of the tasks have been accomplished and the milestones have been reached. Necessary results have been collected by collecting in-operando images.

Reviewer 2:
The reviewer found the technical accomplishments and progress towards overall project to be good. The team obtained electrode image data from cycled electrode material and a developed post-processing pipeline for tomographic reconstructions of cycled electrodes.

Reviewer 3:
Accomplishments seemed good to the reviewer. The team was able to capture the thickness, which is useful information. The reviewer wanted to see the team do a CT scan during transient operation. The reviewer also wanted the team to consider a technique that can capture information about the C.

Reviewer 4:
The reviewer said that the findings of this project were very interesting/surprising. If possible, the cathode expansion study should be tried on a few different electrode designs to see if the results are the same. It would also be interesting to apply the technique to aged cells and anode materials.

Reviewer 5:
The reviewer indicated the project needs more performance indicators and relevant data to augment the quantitative imaging correlation. Simulation needs more quantifiable data points in addition to microstructure imaging.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that the project team collaboration for the modeling project is very good and utilizes the strengths of the national laboratory system.

Reviewer 2:
The reviewer asserted that the partners on the team participated fully in the project. Each member has made a significant contribution to the project.

Reviewer 3:
The reviewer said the partners participated actively and are well coordinated.

Reviewer 4:
The reviewer found good collaboration with different DOE national laboratories. The addition of industry partner and academia will bring more ideas and viewpoints.

Reviewer 5:
The reviewer indicated that there was good collaboration with the beam source and encouraged keeping this collaboration going; however, the reviewer suggested looking at how to use the neutron spallation source. The reviewer would have had CD-adapco focus on developing a DIC-type method that can be used with the transient CT information. This would allow predictions of internal strains within the battery. The reviewer warned against having CD-adapco waste time developing static CT-volume reconstruction. This has been developed already for the medical and industrial CT machines.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the proposed future research is detailed, well-organized, and feasible.

Reviewer 2:
According to the reviewer, researchers identified and proposed effective research plans and addressed critical areas for improvement and opportunities.

Reviewer 3:
The reviewer said that the proposed future research is logical, including milestones and risk management.

Reviewer 4:
The reviewer mentioned that it is unfortunate that this project is ending. The technique has a lot of potential, and it should be developed further using a variety of samples.

Reviewer 5:
The reviewer indicated that the research seems to be going in the direction of transient CT reconstruction and capturing the CT information as the cell is running. However, the reviewer proposed doing this in an industrial or medical CT machine because these data can be captured pretty easily. Also, in these machines, the sample is static and not moving and that would address the issue of samples moving; these machines have solved this issue. The reviewer advocated for having CD-adapco work on the DIC method with transient CT information and looking into using the spallation source to resolve C material. These steps would help several of the other projects, including C, in their simulation.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented that this project supports the overall DOE objectives. This project collected and analyzed in-operando image data of the cycled electrode, which are significant and helpful for the modeling results and support of overall DOE objectives

Reviewer 2:
The reviewer said that the research encompasses all the DOE objectives. Low performance and high cost are the barriers, and the research aims to address these barriers.

Reviewer 3:
The reviewer remarked that this project supports the overall DOE objectives of providing accurate simulation-input data for CAEBAT teams, enabling construction of accurate models to guide cost and performance optimizations.

Reviewer 4:
The reviewer affirmed that the research is relevant to DOE goals.

Reviewer 5:
The reviewer responded affirmatively, and explained that this and the other CAEBAT modeling projects do support the DOE goals to reduce the cost of battery development. The reviewer thought that these projects would greatly benefit from an industry partner to make sure they can be used as intended by Li-ion battery cell designers to lower the development costs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that the resources are sufficient and the stated milestones have been achieved in a timely fashion.

Reviewer 2:
There are sufficient resources allocated to carry out this research, according to the reviewer.

Reviewer 3:
The reviewer stated that the research team has sufficient funding, human resources, and equipment to complete the project.

Reviewer 4:
The reviewer noted that the funds are sufficient, but it would be good to see the project extended into the future.

Reviewer 5:
The reviewer suggested finding a medical or industrial CT machine. DOE National Energy Technology Laboratory has both machines and has run these reconstructions already. DOE Oak Ridge probably has these machines. The reviewer urged just look around within the DOE system as these machines are around. Also, the reviewer suggested getting time on the spallation source at the beam line.

Presentation Number: bat303
Presentation Title: Exploring How Electrode Structure Affects Electrode-Scale Properties Using 3-D Mesoscale Simulations
Principal Investigator: Scott Roberts (Sandia National Laboratories)

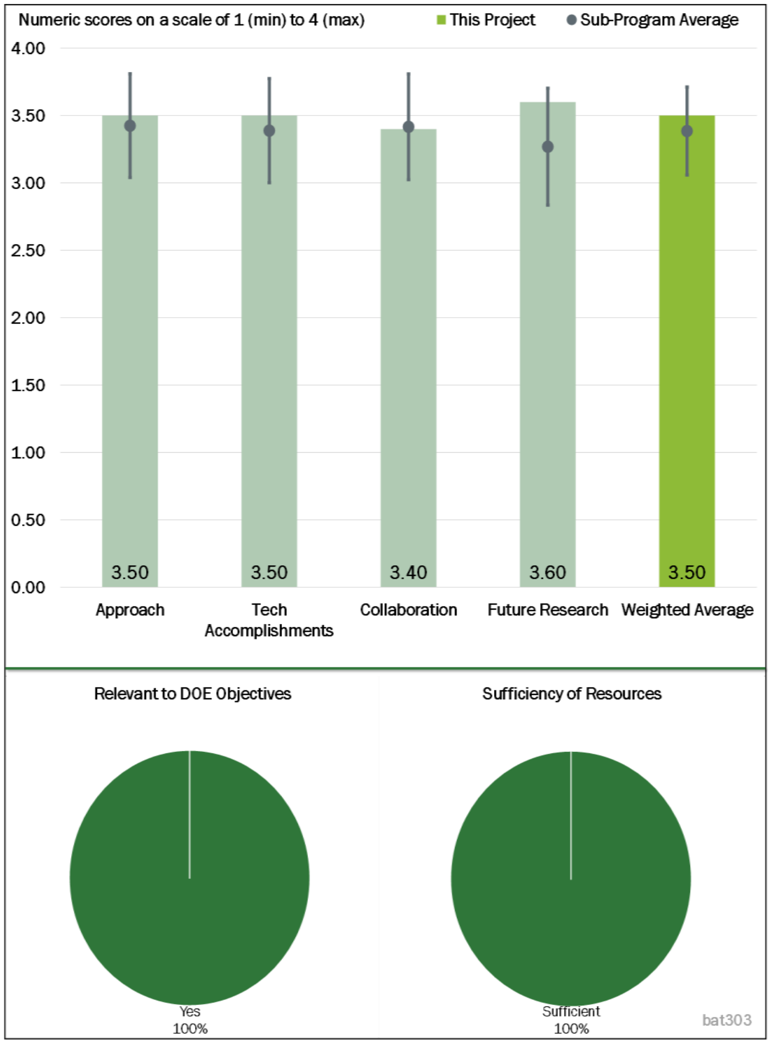

Figure 2-32 - Presentation Number: bat303 Presentation Title: Exploring How Electrode Structure Affects Electrode-Scale Properties Using 3-D Mesoscale Simulations Principal Investigator: Scott Roberts (Sandia National Laboratories)

Presenter

Scott Roberts, Sandia National Laboratories

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer mentioned that the researcher used a different approach to address the technical barrier. The reviewer found the use of the discrete-element method (DEM) to be well designed and a feasible approach. This method allows the researcher to use many attributes of the electrode characteristics and provides a better understanding.

Reviewer 2:

In this project, the reviewer noted that a mesoscale model has been developed to perform coupled, mechanical-electrochemical discharge simulation of the battery. The nanoporosity in the CBD, for the first time, is being included in the mesoscale model.

Reviewer 3:

The reviewer said that, overall, the battery-modeling project is well designed to address the gaps in the current battery-modeling environment.

Reviewer 4:

The reviewer pronounced that approach as seeming good. This DEM method seems interesting and is a good method.

Reviewer 5:

The reviewer commented that the project objective is to understand the decaying behavior of batteries due to cycling through simulation of charging cathode material. To achieve this, the investigation was conducted to understand the effect of different components (i.e., CBD, binder, porosity, etc.) on the properties of the electrode. However, the lack of experimental validations of electrode response impedes the complete effectiveness of the approach.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the project has progressed well during the time duration proposed. The role of electrode parameters on the properties has been investigated pending experimental validation for final refined simulation.

Reviewer 2:

The reviewer said that the method to capture the images of the particles and mesh them at their micro-thickness level provides a good performance enhancement.

Reviewer 3:

The technical accomplishments and progress towards overall project are excellent, according to the reviewer. The team has demonstrated a robust and verified approach for three-phase cathode mesostructure representation and developed an understanding of the role of nanoporous CBD, how to construct them, and scale up the mesoscale results for use in macroscale (ORNL) battery abuse code.

The reviewer wanted to know the pixel and voxel resolution in the images, how the authors can make sure the connectivity of the solid phase is in order to perform continuum simulation, and how the authors can make sure no excessive micro/nanostructure has not been added. The reviewer also asked which machine learning segmentation algorithm was used and whether it was a supervised or unsupervised learning method.

Reviewer 4:

Accomplishments seemed good to the reviewer, who expressed a little concern with the electrical conductivity plot on Slide 12 because the reviewer did not expect the conductivity to be linear. The reviewer asked how the investigators are determining the material properties of the constitutive materials.

Reviewer 5:

The results were interesting to the reviewer, but it is hard to determine the accuracy of the modeling work without correlation with experimental data.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that there is excellent collaboration and engagement with relevant teams to speed up the development process.

Reviewer 2:

The reviewers said that the partners participated actively and are well coordinated.

Reviewer 3:

Collaboration seemed good to the reviewer, who suggested helping the collaborators that are imaging the C formation. The reviewer suggested having the collaborators run Raman spectroscopy to determine the sp2 sp3 content of the C. This will give a better idea of the electrical conductivity.

Reviewer 4:

According to the reviewer, the project team collaboration for the modeling project is very good and utilizes the strengths of the national laboratory system; however, for this project, one focus of the collaboration should be to provide validation data for the models through experimentation.

Reviewer 5:

The reviewer stated that the tasks seem organized and divided among the team collaborators. However, the distinction between LBNL and ANL contribution in tomography is not clear.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the project has identified several points of risks and challenges and addressed them in the future work. Most notably, LBNL/ORNL will be providing experimental data to validate the simulation.

Reviewer 2:

The reviewer found the proposed research very sharply focused on delivering accurate responses. The researcher addressed the risks associated with the barriers and suitable risk-mitigation strategies.

Reviewer 3:

The reviewer said that the proposed future research is logical, including milestones and risk management.

Reviewer 4:

The future work planned for this project addresses the major gaps, according to the reviewer.

Reviewer 5:

The reviewer called the research good and urged continuing to work on the DEM method. Also, the reviewer suggested trying to get a better idea of the properties of the constitutive materials, the sp2 sp3 content of C.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer pointed out that the project is tightly related to DOE objectives because it addresses energy security and efficiency topics. It is understood that the outcome of this project could potentially limit the loss of energy and power in batteries used in vehicles by simulating and abusing cathode electrodes.

Reviewer 2:

The reviewer commented that the loss of power and energy and abuse tolerance, reliability, and ruggedness are the barriers and the DOE objective of improving the fidelity of battery-scale simulation fits the bill perfectly.

Reviewer 3:

The reviewer said that this project supports the overall DOE objectives by improving the fidelity of battery-scale simulations of abuse scenarios through the creation and application of microscale (particle-scale) electrode simulations

Reviewer 4:

The reviewer affirmed that the project was very relevant to DOE goals of improvements in battery technology.

Reviewer 5:

The reviewer responded affirmatively, and elaborated that this and the other CAEBAT modeling projects do support the DOE goals to reduce the cost of battery development. The reviewer thought that these projects would greatly benefit from an industry partner to make sure they can be used as intended by Li-ion battery cell designers to lower the development costs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewed agreed that sufficient resources are available to the researcher to accomplish the project milestones in a timely fashion.

Reviewer 2:

The reviewer stated that the research team has sufficient funding, human resources, and equipment to complete the project.

Reviewer 3:

The reviewer stated that the funds are sufficient, but it would be good to see the project extended into the future.

Reviewer 4:

The resources seemed appropriate and sufficient to the reviewer. Large-scale simulation has been undertaken, and the lack of experimental validation due to unavailability of raw data for validation is the only missing link for the ongoing simulation.

Reviewer 5:

Resources seemed good to the reviewer, who wanted to see a couple of additional experimental methods to determine materials of constitutive materials.

Presentation Number: bat307
Presentation Title: Discovery of High-Energy Lithium-Ion Battery Materials
Principal Investigator: Wei Tong (Lawrence Berkeley National Laboratory)

Presenter

Wei Tong, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

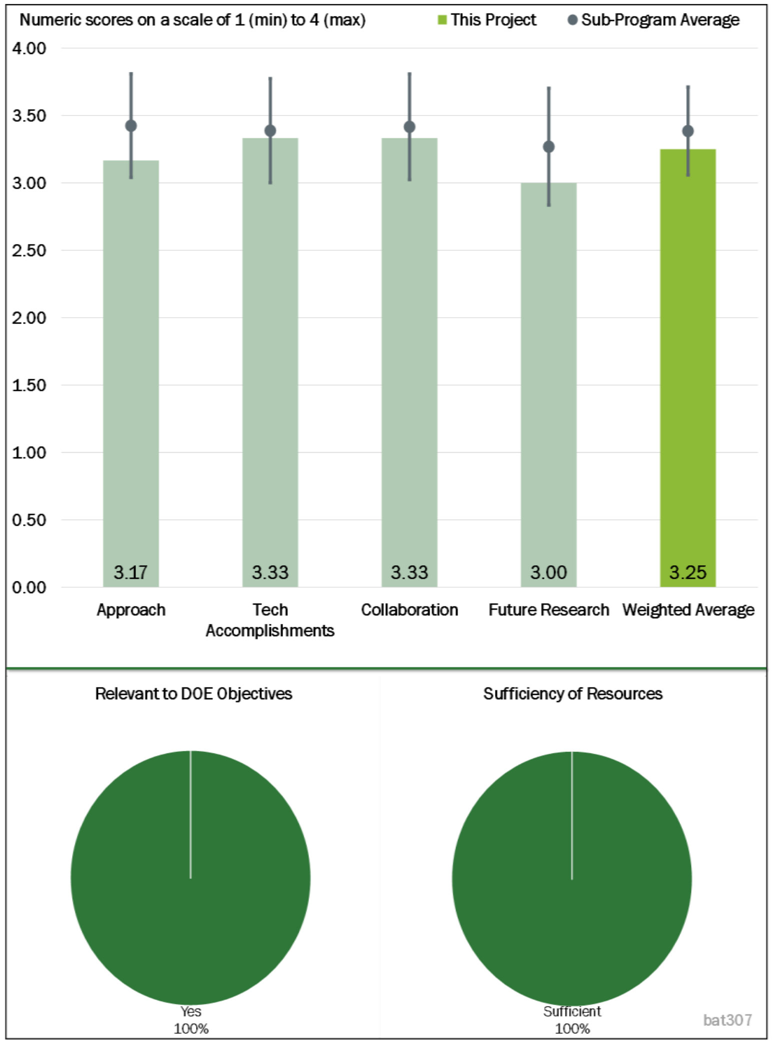

Figure 2-33 - Presentation Number: bat307 Presentation Title: Discovery of High-Energy Lithium-Ion Battery Materials Principal Investigator: Wei Tong (Lawrence Berkeley National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the approach of this research is to design novel Ni-based cathode materials with potentially high energy density by integrating a second TM to improve the structural stability and/or contribute electrochemically active redox. Overall, the proposed approach can break the technical barriers as mentioned in the report.

Reviewer 2:

The reviewer said that this project designs compositions that contain excess Li and utilizes Ni^{2+} to Ni^{4+} redox along with a second TM to achieve high capacity and good structural integrity. The project is investigating the impact of anionic oxygen activity on voltage fade in Li-rich metal oxides by combining DEMS, advanced synchrotron spectroscopy, and electrochemical characterization; finally, materials are designed to elucidate the potential impact of TMs on oxygen activity during electrochemistry.

Reviewer 3:

The reviewer pointed out that the research question central to this project is an important one: namely, that oxygen redox may play a critical role in voltage fade in Li-rich layered oxides. However, the results for this year focus almost exclusively on understanding the case where no oxygen redox is present. The results thus confirm the role of only transition metal (Ni and ruthenium) redox in $Li_{1.2}Ni_{0.2}Ru_{0.6}O_2$ (LNRO). The choice to work on LNRO is somewhat questionable to the reviewer because of the inherent cost barrier in using materials with ruthenium; however, in discussions during the poster session, the PI explained that this is merely a control material for comparison with high-Li nickel manganese oxide (LNMO). Some data for LNMO are presented, but comparisons are insufficient to demonstrate the desirability of oxygen redox (or not). It was somewhat interesting to the reviewer that with different Ni/ruthenium ratios, oxygen redox is still irrelevant in LNRO, a topic that could be explored further. The electrochemical characterization and XAS measurements (plus scanning transmission electron spectroscopy [STEM]) lead to somewhat speculative conclusions about the reason for voltage fade, which needs to be clarified. To the reviewer, this project should refocus on showing conclusively that voltage fade is related to the formation of a second crystal phase in LNRO and that this mechanism is either relevant or irrelevant in LNMO.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

According to the reviewer, the technical accomplishments and progress are excellent. The research proceeds in a logical manner, and many characterization techniques have been used to get to a full understanding of the structural information of the cathode materials. All of the achievements are critical to realize the overall goals of the project.

Reviewer 2:

The reviewer opined that this project found competition between TM redox and oxygen redox. Voltage fade phenomena were observed in LNRO, but at a much lower degree. The layered monoclinic structure likely contributes to voltage fade during cycling.

Reviewer 3:

The reviewer commented that a Li-rich layered oxide has been studied that does meet the go/no-go criteria of 200 mAh/g. To the reviewer, this target is not ambitious enough because commercially available NMC-622 already exceeds this at higher charge/discharge rates. Little effort seems to have been made to quantify performance metrics for LNRO like voltage fade over reasonably large numbers of cycles, which is an unfortunate oversight. One could easily argue that LNRO is not commercially relevant and that it does not help the project team study the critical question of oxygen redox in Li-rich layered oxides, but as a control, studying this material does produce some insights into cathode degradation mechanisms.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that this project had collaboration among many national laboratories and universities as shown in the presentation

Reviewer 2:

The reviewer noted that there is work with the SSRL, the Advanced Light Source (ALS), the Advanced Photon Source, and the University of California at Berkeley (UCB).

Reviewer 3:

The reviewer stated that collaboration across the project team seems effective, but additional detail is needed on how complementary each contributor is to the larger effort.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the work is planned in a logical manner.

Reviewer 2:

Overall, the proposed future work is excellent, according to the reviewer, who suggested that the PI should also pay more attention to the gassing issue. Approaches to depress the gas releasing during the battery cycling need to be addressed.

Reviewer 3:

The reviewer commented that the proposed future work is reasonable; however, after nearly 3 years, the reviewer expected that much of what is being proposed would already have been investigated. The remaining questions should have been as obvious at the beginning of this project as they are now.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer stated that the project goals including developing a cathode that can cycle greater than 200 mAh/g while exhibiting minimal capacity and voltage fade in order to gain an in-depth understanding of the correlation between composition and electrochemistry in Li-rich layered oxides.

Reviewer 2:

The reviewer commented that DOE overall target is to develop Li-ion batteries with low-cost, high energy density, and high electrochemical properties. The target of this project is consistent with DOE's goals. However, as Ni-rich NMCs reach 250 mAh/g, the PI of this project should target even higher capacity cathode materials.

Reviewer 3:

The reviewer remarked that this project does attempt to address DOE objectives concerning the development of higher energy cathode materials; however, the output could have been better given the resources and time spent.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the resources from many national laboratories and universities are sufficient to support the research work of this project.

Reviewer 2:

The reviewer commented that for the amount of relevant work produced in the project, the resources have been sufficient or underutilized compared to projects with similar budgets.

Reviewer 3:

The reviewer noted that this project achieved two out of four milestones.

Presentation Number: bat310
Presentation Title: Advancing Solid-State Interfaces in Lithium-Ion Batteries
Principal Investigator: Nenad Markovic (Argonne National Laboratory)

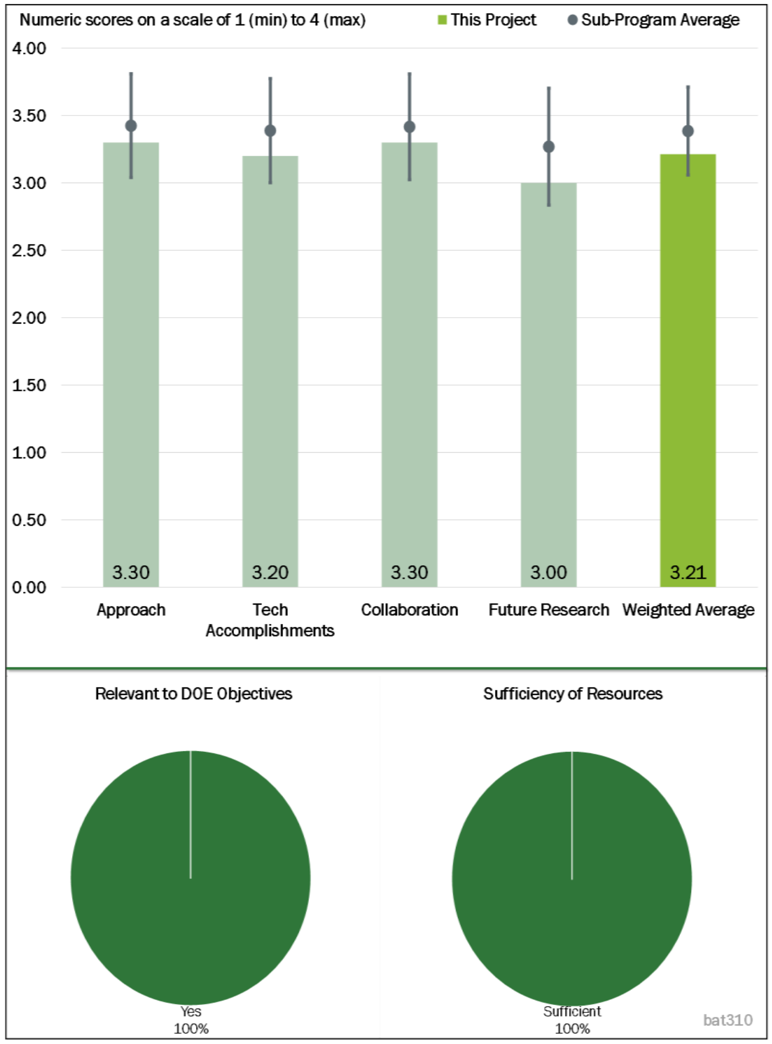

Figure 2-34 - Presentation Number: bat310 Presentation Title: Advancing Solid-State Interfaces in Lithium-Ion Batteries Principal Investigator: Nenad Markovic (Argonne National Laboratory)

Presenter

Nenad Markovic, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the team has done an excellent job in studying the solid-solid interfaces in Li-ion batteries. The team employed science-based, multiscale experimental, and computational approaches to develop a mechanically/chemically stable, Li-ion, conductive, nonflammable solid electrolyte. The team has successfully identified several elements that are critical for such an electrolyte. The project started in 2016, and the reviewer opined that it has made remarkable progress in addressing the technical barriers.

Reviewer 2:

The reviewer found the approach of integrating glove box, sputtering, and X-ray photoelectron spectroscopy (XPS) to be excellent. The XAS, XRD, and hard X-ray photoelectron spectroscopy (HAXPES) are all great techniques for searching for answers to the key questions of interfacial processes in rechargeable batteries. Therefore, the approach is excellent.

Reviewer 3:

The project addresses a critical need of understanding the stability of different SSEs versus Li, whether the Li is cleaned or not, and the delay in growth of impedance layers due to already formed impedance-inducing contamination layers.

Reviewer 4:

The reviewer commented that studying electrochemical interfaces for solid electrolytes will help advance solid-state battery technology, although the project scope did specify this. Using modeling tools to study a range of materials is great and helpful; however, the reviewer stated that it would be more realistic if a battery system were specifically chosen and used--for example, NMC/LLZO/lithium (all solid-state cells)—to study the materials behavior during battery cycling at room and elevated temperatures.

Reviewer 5:

The approach seemed good to the reviewer, who stated that XPS is a great method to look at the energetics. The reviewer thought that the PI should focus a little more on understanding the XPS data.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the team has demonstrated several technical accomplishments and progress in the overall project. The project is in good shape in terms of milestones. The team has not reported much in terms of mechanics of solid electrolytes, which are important for developing mechanically robust solid electrolytes.

Reviewer 2:

The reviewer commented that the team has shown progress on the oxide structures and especially the stability versus a contaminated and non-contaminated Li source. There is still a significant amount of work to do to show stability against multiple SSE-based electrolytes and common contaminants (including moisture-based decomposition products).

Reviewer 3:

The reviewer found that very useful electrochemical data on lithium lanthanum zirconium molybdenum oxide (LLZMO) materials were generated in the program so far. Any potential impact of these material changes on cell performance should be studied in the future.

Reviewer 4:

The information generated looked good to the reviewer, who really liked the XPS data as a function of temperature. The reviewer said that the team should be able to calculate the binding energy of the surface species and suggested calculating some binding energies from these data. The data can be used with first-principle modeling (which the reviewer suggested for future work) to get a better understanding of the energetics. It seemed to the reviewer that doping is not really doing much to this structure (Slide 16), and the reviewer expected a little more change. The reviewer asked what the concentrations are.

Reviewer 5:

The reviewer stated that the overall progress of the project appears to be on track against what has been proposed. The proposed technique and approach are excellent. However, it appeared to the reviewer that the research outcome is very limited, with only one paper accepted and one under preparation. This appeared off to the reviewer when benchmarked with other projects.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the group at ANL has outstanding facilities and an in-depth knowledge of model surfaces.

Reviewer 2:

According to the reviewer, the ANL team has done a good job collaborating with DOE national laboratories and universities.

Reviewer 3:

The reviewer found all the collaboration teams to be leading experts on the proposed direction.

Reviewer 4:
The reviewer noted that the team has demonstrated several good collaborations in experimental characterization and modeling. More collaborations are needed to study the mechanics of the developed electrolytes, which must be mechanically robust as well.

Reviewer 5:
Collaboration seemed fine to the reviewer, who suggested that the team get in contact with someone doing first-principle modeling (density functional theory [DFT]) to compare some of these binding energy predictions against. This would be really interesting.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the team proposes to focus on a Li solid-electrolyte system and a cathode solid-electrolyte system. These are outstanding challenges for solid-state battery system based on a Li-metal anode, SSE, and cathode.

Reviewer 2:
The reviewer indicated that the future project plan would complete the survey of all the different SSE materials and their stability against Li and Li contaminants; this is a desired result.

Reviewer 3:
The reviewer remarked that the proposed future work is well planned and suggested that the team study the microstructure and mechanical property changes during cycling. It is important to establish the relation between microstructure (grain size and defects) and chemical and mechanical properties of the developed electrolytes.

Reviewer 4:
The reviewer expressed concern with the overall method and somewhat with the technical gap between using “lithium/SSE/lithium” as a platform in modeling and using battery cells. According to the reviewer, there are some reports of Li dendrites growing through LLZO grain boundaries; meanwhile, some companies demonstrated good cycling solid-state cells without observing negative impacts of Li dendrite growth. This is a good indication that battery cell configurations, such as cathode/SSE/Li, could be a more realistic modeling platform than Li/SSE/Li.

Reviewer 5:
The reviewer recommended collaborating with someone doing DFT calculations as this might help to explain the chemistry a little better.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer affirmed that to enable Li anodes especially at higher rates, it is necessary to understand which SSE is stable against Li and what is required for surface cleaning for the lithium.

Reviewer 2:
The reviewer opined that studying SSEs on both structures and interface issues will help advancing solid-state battery technology so this project supports the overall DOE objectives.

Reviewer 3:
The reviewer remarked that high-performance solid electrolytes are greatly needed for the next generation of batteries. There are several challenges, such as chemical stability, mechanical robustness, and compatibility between the solid electrolyte and the electrode, which are less or completely unknown.

Reviewer 4:
The reviewer pronounced the project as relevant to DOE.

Reviewer 5:
The reviewer stated that solid-state batteries have been viewed as the future of the rechargeable battery for safe operation, while the interfacial process is the key. In this sense, the project rightly purged on this topic.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that ANL has several unique instruments that are critical to the success of this project. The team has employed the combined glove box, sputtering, and XPS chamber system. Using XAS, XRD, and HAXPES is also helpful.

Reviewer 2:
The reviewer indicated that the resources appear to be commensurate with what can be done.

Reviewer 3:
The reviewer commented that the resources for the project are sufficient to achieve the stated milestones.

Reviewer 4:
The reviewer observed that the current resources are sufficient to achieve the project targets.

Reviewer 5:
The reviewer stressed doing some DFT calculations and using an HPC system to find someone who can help with first-principle calculations.

Presentation Number: bat312
Presentation Title: Advanced Lithium-Ion Battery Technology: High-Voltage Electrolyte
Principal Investigator: Joe Sunstrom (Daikin)

Presenter

Joe Sunstrom, Daikin

Reviewer Sample Size

A total of five reviewers evaluated this project.

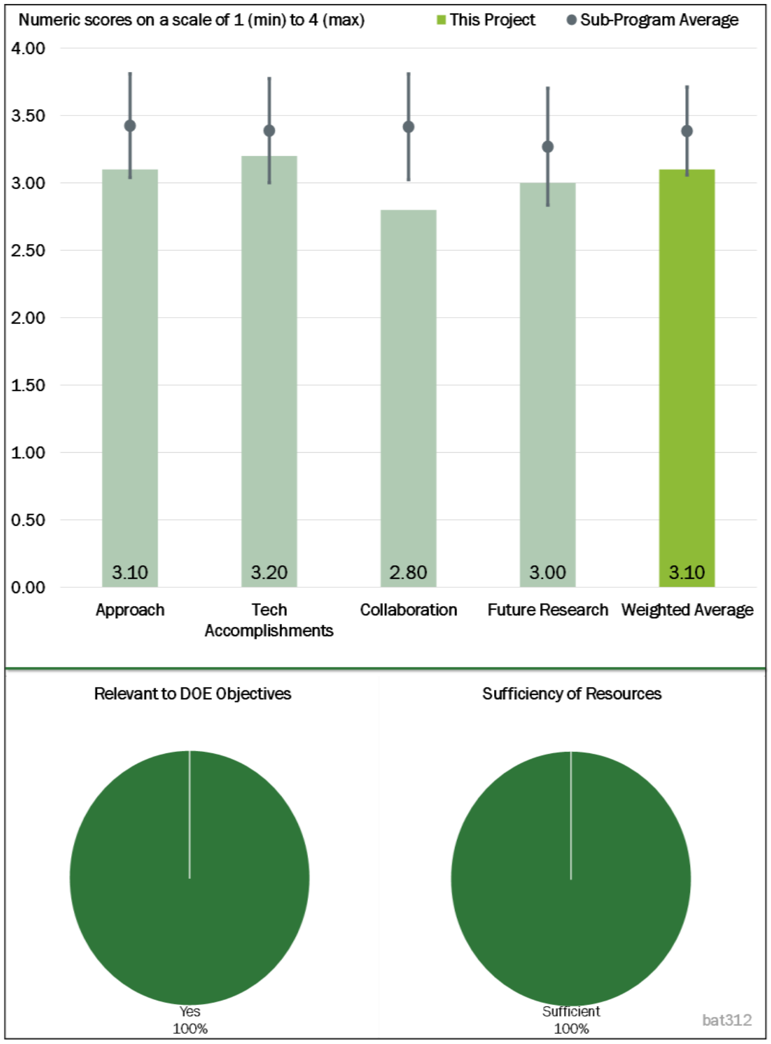

Figure 2-35 - Presentation Number: bat312 Presentation Title: Advanced Lithium-Ion Battery Technology: High-Voltage Electrolyte Principal Investigator: Joe Sunstrom (Daikin)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the Daikin team has done an excellent job in developing high-voltage electrolytes for Li-ion batteries. The team has discovered several new failure mechanisms. The correlation between SEI and gas generation has been established. The project started in 2016 and has made remarkable progress in addressing the technical barriers.

Reviewer 2:

The reviewer pointed out that using fluoroethylene carbonate (FEC) additives to stabilize electrolytes at higher voltages is cost effective; however, this might not be able to fundamentally solve the problem. The maximum 4.6 V voltage range proposed in the project is somewhat low because there is 5V LNMO-C chemistry available currently. Studying gassing is useful and necessary; however, the project does not seem to establish methods to differentiate any possible gassing contributions from other cell components (binders, additives, separator coatings, as well as other cell components exposed to the electrolyte) other than the electrolytes. With its expertise in fluorine chemistry, Daikin America is a good company to develop all fluorinated electrolytes with a focus on lowering the cost.

Reviewer 3:

The approach seemed good to the reviewer, who proposed measuring the dielectric strength of the material.

Reviewer 4:

The barriers to high-voltage electrolytes are being addressed through development of an understanding of the failure mechanism. The plan for mechanistic understanding is detailed and very good. There does not seem to be a very well-designed plan for finding electrolyte additives and what there is comes at the end of the 3-year period.

Reviewer 5:
The reviewer stated that the team is focusing on exploring the stability of electrolytes for long cycle life. The main research topic appears to be focused on compatibilities between the electrolyte and the cathode for high-voltage operation up to 4.6V. Also, it was hard for the reviewer to know if the fading at high voltage is due to the failure of the electrolyte or due to the cathode itself. For the anode side, depending on the anode, the interfacial reaction will also play a big role in terms of stability.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that the team has demonstrated several technical accomplishments and progress. The project is in good shape in terms of milestones. The reviewer suggested that modeling of the electrolyte/electrode be carried out.

Reviewer 2:
The reviewer noted that it looks like the team has achieved the 4.6V target already.

Reviewer 3:
According to the reviewer, excellent progress has been made on the failure mechanisms of high-voltage electrolytes through the systematic studies. Not much progress on the development of new additives is evident.

Reviewer 4:
The reviewer indicated that it is known that gassing will take place at higher voltages for LCO/NMC/nickel cobalt aluminum oxide (NCA) cells. The project generated some useful data regarding gas composition, etc. Although gassing in cells is a messy, complicated problem, the project should at least make an effort to speculate about what the various sources are and the mechanisms to explain the gas composition.

Reviewer 5:
The reviewer said that the team has made some good progress in analyzing the composition of the gas, while the overall work appears to have been carried out in a trial-and-error manner. The major weak point is the lack of a fundamental hypothesis and proof of concept. A systematic approach may be complementary to the trial-and-error method.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that the collaboration seems good, and Daikin seems interested in doing the research.

Reviewer 2:
The reviewer encouraged the team to reach out more to collaborate with other groups to work on the surface of both the cathode and anode. A collaboration with a microscopy group to study the surface of both anode and cathode as a variation of electrolyte chemistry could be very beneficial to the project.

Reviewer 3:
The reviewer found not much in the way of collaboration. However, that is understandable as most of the characterization is being done in-house.

Reviewer 4:
The team did not show any collaboration with national laboratories and universities, according to the reviewer, who suggested that the team reach out to collaborate with modeling groups at national laboratories and universities.

Reviewer 5:
The reviewer stressed that, even not as formal project subcontractors, national laboratories and universities should be involved more in the project to help with the electrolyte-degradation study.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the proposed future work is within the project scope and there are some efforts proposed on collaboration with outside resources.

Reviewer 2:
The reviewer found the proposed future work to be well planned, and suggested that the team study the atomistic-/molecular-level interactions between the electrolyte and the electrode during/after cycling at high voltages.

Reviewer 3:
The reviewer urged the team to keep going, run more experimental tests, and consider any health or environmental hazards that might impede this technology from making it into the consumer market.

Reviewer 4:
The reviewer remarked that the proposed research for this project is largely on failure mechanisms and the characterization approaches. It seems to lack much in the way of plans for the development of electrolyte additives.

Reviewer 5:
The reviewer pronounced the proposed research as good, but as the research converges towards the end of the project, the team should be more hypothesis driven based on what has been learned rather than still trial-and-error. Computable electrolyte computable for both cathode and anode needs to be considered from this reviewer's perspective. By focusing only on cathode electrolytes, the reviewer was very dubious about whether the optimized electrolyte will work or not for the case of the anode side.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that the overall objective of optimizing the electrolyte towards high-voltage operation of the battery is very relevant for VTO.

Reviewer 2:
The reviewer commented that high-performance electrolytes facilitate stable, high-voltage cycling of Li-ion batteries, presenting a pathway to higher energy batteries that is beneficial towards DOE cost targets ($/kWh).

Reviewer 3:
The reviewer said that stabilizing electrolytes at higher voltages helps extend battery life and increases cells' energy density. This project supports the overall DOE objectives.

Reviewer 4:
The reviewer commented that the research is relevant to the DOE objective of finding electrolytes to enable high-voltage cathodes.

Reviewer 5:
The reviewer said that the project was relevant to DOE.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that resources for this project are sufficient to achieve the stated milestones.

Reviewer 2:
The reviewer indicated that resources at Daikin are sufficient.

Reviewer 3:
The reviewer said that the resources are good as compared with other, similarly scaled work.

Reviewer 4:
The team has fully used the resources at Daikin, according to the reviewer, who suggested that the team reach out to national laboratories and universities to do modeling.

Reviewer 5:
The reviewer stated that there are good resources and encouraged measuring the dielectric strength of the electrolyte.

Presentation Number: bat319
Presentation Title: Advanced Microscopy and Spectroscopy for Probing and Optimizing Electrode-Electrolyte
Principal Investigator: Shirley Meng (University of California-San Diego)

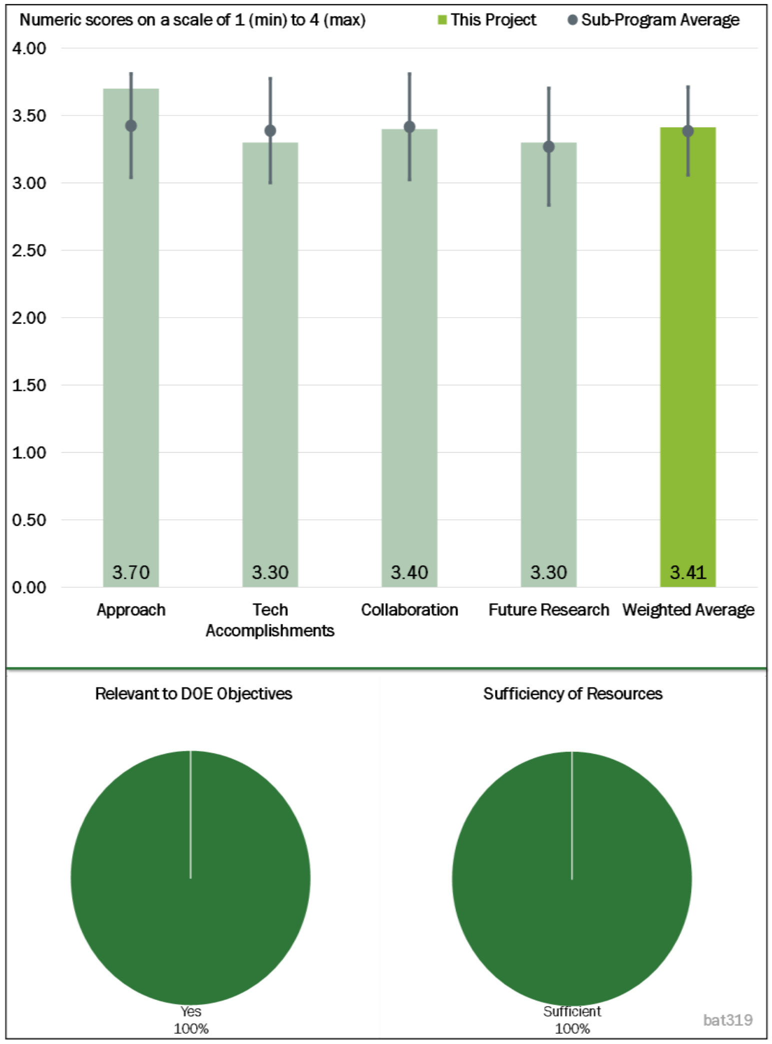

Figure 2-36 - Presentation Number: bat319 Presentation Title: Advanced Microscopy and Spectroscopy for Probing and Optimizing Electrode-Electrolyte Principal Investigator: Shirley Meng (University of California-San Diego)

Presenter

Minghao Zhang, University of California-San Diego

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer praised the team’s excellent work in studying electrode/electrolyte interphases in Li batteries. The team uncovered the anion redox and oxygen evolutions in Li-excess NMC materials and tracked the Li and oxygen dynamics under electrochemical testing. The study on the chemical composition and structure of electrochemically deposited Li metal is of great interest. The project started in 2016 and has made remarkable progress in addressing the technical barriers.

Reviewer 2:

The reviewer said that there is a good combination of state-of-the-art characterization techniques to probe anion redox and oxygen evolutions in Li-excess NMC materials. In addition, in-operando neutron diffraction will be used to study dynamics and strategies for synthesis of modified cathode materials are proposed.

Reviewer 3:

The reviewer found that very useful microscopy and spectroscopy techniques for probing battery electrodes have been demonstrated in this program. The lithium lanthanum titanate (LLTO) coating on the Li-rich, layered-oxide cathode materials is a good idea, and the same concept could be used on other cathode materials as an effective way to improve cells’ cycle life.

Reviewer 4:

The reviewer commented that the approaches include a combination of microscopy, neutron scattering, and X-ray diffraction. All these cutting-edge techniques reveal certain aspects of information about battery materials. Therefore, an integrated use of these different techniques will help to capture complementary information for understand battery failure.

Reviewer 5:
The approach seemed good to the reviewer, who pronounced the experimental methods to be appropriate.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer remarked that excellent progress has been made on probing various aspects of electrode-electrolyte interphases, including Li-rich oxides and coatings. The characterization techniques are yielding useful information.

Reviewer 2:
The reviewer commented that this proposed work is an excellent addition to the toolbox of current battery research and development. The project generated very useful data that will shed light on battery-materials optimization.

Reviewer 3:
The reviewer stated that the team has demonstrated several technical accomplishments and progress in the overall project. The project is in good shape in terms of milestones. The reviewer suggested carrying out modeling of the electrolyte/electrode interphases.

Reviewer 4:
Accomplishments seemed fine to the reviewer, who was not sure about the point of being able to reheat the cathode material to regenerate it. The reviewer said that the PI should think about how to stabilize the phase, and maybe what substrates may stabilize the phase.

Reviewer 5:
The reviewer noted that the diagnostic results provide certain insights on the degradation mechanism of a Li-rich cathode. However, the reviewer was very doubtful about the heat-treatment scheme for resolving the fading problem of this category of cathode or, in other words, how the heat-treatment strategy can be used for a battery system to resolve the fading problem.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
According to the reviewer, excellent collaboration and coordination across the project teams has been achieved in this program.

Reviewer 2:
The reviewer pointed out that the team has a good collaboration with teams that have different skill sets.

Reviewer 3:
The reviewer noted that numerous collaborations enhance the project.

Reviewer 4:
The reviewer acknowledged that the team has been collaborating with national laboratories and universities and suggested that the team reach out to collaborate with modeling groups at national laboratories and universities.

Reviewer 5:
Collaboration seemed good to the reviewer. There was mention of potentially doing some DFT calculations. The reviewer suggested that the PI collaborate with an expert who has experience doing DFT calculations. This would be a better use of resources instead of the PI having their students learn how to use DFT software.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

To the reviewer, the plans for the Li-rich layered oxide (LRLO) materials as well as the Li anode seem well defined and make use of state-of-the-art characterization methods. The theory does not seem well integrated yet, and it is not clear how the DFT methods can be used to study heat treatment in these materials.

Reviewer 2:

The proposed future work is well planned, according to the reviewer who suggested that the team study the atomistic-/molecular-level interactions between the electrolyte and the electrode during/after cycling at high voltages.

Reviewer 3:

The reviewer remarked that the proposed future work is within the project scope and well planned. The reviewer is concerned, however, by the effort/focus on "recovering" the structures and voltage of LRLO materials. Recovering the LRLO structures, using either thermal or pressurizing methods, is some post-processing for battery materials, not something realistic for a fabricated cell in service or being beneficial to overall cell performance. Focusing on improving LRLO or other cathodes performance in cells by nanometer coatings, etc., will make this program very relevant and more productive. The reviewer, however, understands that this is probably not part of the original work plan.

Reviewer 4:

The reviewer proposed focusing on stabilizing the phase and asked what substrates can be used to help stabilize the phase. The reviewer would also use DFT to help understand the stability in order to calculate the formation energy of the phase deposited on different substrates. The reviewer would not mess with the nudged elastic band method. Again, the reviewer suggested that the PI collaborate with someone who has experience conducting DFT simulations.

Reviewer 5:

The proposed future research appeared to the reviewer to be on track with the overall objectives of the proposed research. However, the reviewer was very conservative regarding the method of heat treatment and high-pressure treatment for resolving the fading problem. The reviewer asked how these two methods can be implanted in an assembled battery.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer found the proposed research to be very relevant to DOE objectives. Finding the fading mechanism and a way of mitigating the fading of the cathode is critical to advancing battery technology for electrified cars.

Reviewer 2:

The reviewer stated that understanding the electrode/electrolyte interphases in Li batteries is critical to achieve the goals of an energy density of 500 Wh/kg and 1,000 charge/discharge cycles.

Reviewer 3:

The reviewer commented that this program strongly supports the overall DOE objectives.

Reviewer 4:

The reviewer said that the project supports the development of new battery materials.

Reviewer 5:
The reviewer affirmed that the project is relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The team has fully used the resources at the University of California at San Diego, DOE national laboratories, and Cornell University, according to the reviewer, who suggested that the team reach out to national laboratories and universities to do modeling.

Reviewer 2:
The reviewer noted that the current resources of this program are sufficient to achieve the stated milestones in a timely fashion.

Reviewer 3:
The reviewer reported that an appropriate amount of resources is assigned to this project.

Reviewer 4:
The reviewer remarked that the resources are sufficient.

Reviewer 5:
The reviewer pronounced resources to be good, and asked that the team please use the HPC system to run DFT calculations.

Presentation Number: bat321
Presentation Title: Solid-State Inorganic Nanofiber Network-Polymer Composite Electrolytes for Lithium Batteries
Principal Investigator: Nianqiang Wu (West Virginia University)

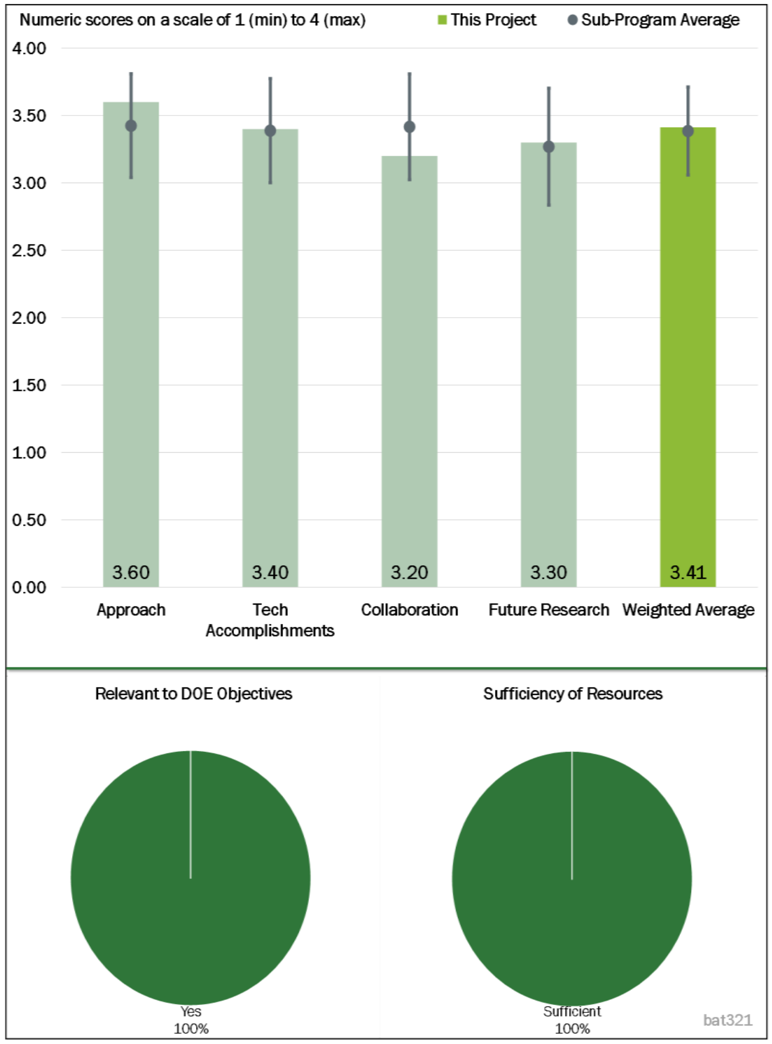

Figure 2-37 - Presentation Number: bat321 Presentation Title: Solid-State Inorganic Nanofiber Network-Polymer Composite Electrolytes for Lithium Batteries Principal Investigator: Nianqiang Wu (West Virginia University)

Presenter

Nianqiang Wu, West Virginia University

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the technical approach is very good as it addresses one of the key technical barriers addressing Li-metal rechargeable batteries. The ionic conductivity of these solid-polymer electrolytes is relatively low, and this therefore severely hinders their use in Li-metal batteries. The PI is attempting to decrease the crystallinity of polymers by the addition of inorganic nanofibers, which the reviewer opined should improve ionic mobility and lay out a feasible path.

Reviewer 2:

The reviewer remarked that the approach, based on a composite electrolyte of a polymer matrix and inorganic fibers, is part of a strategy to address both ionic conductivity and interfaces needed for good SSEs. The approach is well designed and worthwhile to try as it could overcome problems with ionic conductivity of polymers at room temperature as well as interface problems.

Reviewer 3:

The reviewer called the design of the composite electrolyte system very nice and technically sound. The ultraviolet (UV) curing process makes the whole separator system very versatile and practical.

Reviewer 4:

The reviewer commented that the approach in this project involves fabrication of a hybrid solid electrolyte, based on polymer matrix and inorganic fibers with high ionic conductivity and mechanical robustness. An interesting aspect of the approach is the in situ polymerization of the electrolyte on the surface of a cathode, which can enable better cathode/electrolyte interface. In this approach, the electrolyte is in its liquid form, and it can penetrate through pores in a composite cathode leading to the increased cathode/electrolyte contact area and overall improved electrochemical performance of the battery. This is not needed for the anode/electrolyte interface as the anode is a metallic Li with no pores.

Reviewer 5:

The reviewer said that the main objective of this work is to develop a polymer matrix and inorganic, composite SSE for a full solid-state battery. The reviewer liked the idea of this type of composite. The project team currently intends to increase the ionic conductivity of both inorganic and polymer materials to enhance the composite ionic conductivity. This is logically correct. In the reviewer's opinion, the interface between the matrix and the dispersed inorganic particle will be also critical, which has been demonstrated for the case of a high-temperature oxygen conductor.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that good progress has been achieved thus far. The group has synthesized three precursors and monomers for block co-polymers, and has also prepared a block co-polymer, and synthesized three different types of inorganic nanofibers. The team appears to be on schedule.

Reviewer 2:

The reviewer said that the work was systematically conducted, with a combination of experimental and theoretical calculations. The reviewer liked the step-by-step approaches, and the composite electrolyte made so far shows stable cycling based on Li metal and LFP.

Reviewer 3:

The reviewer remarked that very good cell results were demonstrated using a composite solid-state separator system, and the solid-state electrolyte showed much improved ionic conductivity and mechanical properties over other SSE. The demonstrated UV-curable process for fabricating the cathode is particularly interesting. The interfacial issues generally associated with solid-state batteries were nicely mitigated in this project.

Reviewer 4:

The reviewer commented that progress has been made in the synthesis of polymers and inorganic fibers with good conductivity and stability properties. However, the composites still do not have the necessary ionic conductivity; the idea that the nanofibers would decrease crystallization does not appear to have solved the conductivity problem of the polymers.

Reviewer 5:

The reviewer said that, first, a salt-added, cross-linked polymer, Li electrolyte with the ionic conductivity of 2.40×10^{-4} Siemen per centimeter (S/cm) was synthesized, thus reaching a goal for the polymer matrix conductivity. Second, measurements of ionic conductivity in the Al- and nitrogen-doped LLTO inorganic nanofibers revealed that 0.5% aluminum-doped LLTO exhibited the highest ionic conductivity (1.08×10^{-3}S/cm) of all synthesized samples, thus reaching a goal for the inorganic fibers conductivity. Third, a composite electrolyte made of a cross-linked polymer matrix and inorganic fibers was fabricated. It was shown that the addition of inorganic fibers improved mechanical properties and the Li transference number of the polymer matrix.

The reviewer posed several questions. Despite the fact that the ratio between the polymer matrix and inorganic fibers was varied, it remained unclear to the reviewer how both ionic conductivity and mechanical properties of the composite electrolyte change as the ratio between polymer and fibers changes. The reviewer wanted to know if there is an optimum ratio that provides the highest ionic conductivity and best mechanical robustness, including suppression of lithium dendrite growth. Next, the reviewer stated that the goal to understand the mechanism of ion transport that involves three alternative routes—Li transport through polymer matrix, Li transport through inorganic fibers, and Li transport at the interface between the polymer component and fibers—is important to design and fabricate solid electrolytes with best electrochemical performance. The team is encouraged to test composites made of non-conductive polymer and conductive inorganic fibers with different ratios between the polymer and fiber components to evaluate electrochemical performance of fibers only. The reviewer pointed out that there is only one paper reported to be published during the reporting period. To strengthen the team's appearance in the solid-electrolyte community, the reviewer encouraged the team to publish more. Given the number of the reported manuscripts under preparation, this seems not to be an issue in the future; however, at the moment the number of published papers is not high.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found that the project demonstrated good collaboration and coordination across project teams.

Reviewer 2:

The reviewer remarked that the project has several collaborations, including for theory and synthesis,

Reviewer 3:

The reviewer noted that collaboration exists with North Carolina State University.

Reviewer 4:

The reviewer stated that the project lead is West Virginia University, and all types of experiments can be and are being conducted at this institution. The key partner, North Carolina State University, provides complimentary investigation of polymer matrix design, synthesis, and characterization as well as full cell testing. It would be helpful if the PI added the name of the partner to evaluate collaborative publications.

Reviewer 5:

The reviewer stated that the project team is collaborating with a theoretical group and other two groups. In the reviewer's opinion, the team can collaborate more widely with other battery groups to extend to other possible materials system both in the polymer and inorganic particles.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that future efforts are logical and justified by the results thus far. The project team will optimize and develop new polymers and modify the ceramic nanofiber surface to create a buffer layer at the ceramic-polymer interface.

Reviewer 2:

The reviewer said that the proposed future research addresses the key barriers of the project. The team proposal to focus on enhancing both the bulk and interfacial conductivity is the right approach.

Reviewer 3:

The reviewer observed that the future plans of the project include improvements in polymers, inorganic nanofibers, and composites. The plans for the most part are sensible, but plans for improving the conductivity of the polymer are not well defined.

Reviewer 4:

For the project PI's consideration, the reviewer suggested the following in future work to further validate the proposed technology: Demonstrate other battery formats, such as pouch cells; demonstrate multi-layer pouch cell configuration and performance; demonstrate that the solid-electrolyte system can be used for LCO, NMC, NCA, and other chemistries; and finally and most importantly, evaluate the cell performance and report cell performance based on cell weight, kWh/kg per cell.

Reviewer 5:

The reviewer said that the team proposes further increasing the ionic conductivity of their composite electrolyte using strategies such as doping of inorganic nanofibers, applying highly conductive coatings, and modifying the interface. Additionally, the team proposes to test symmetric and full cells. In order to develop a composite electrolyte with the performance best suited for commercial batteries, the reviewer opined that it is important that the team understands better the role of the polymer matrix/inorganic fibers interface and develops ways to control this interface. The strategies proposed by the team, combined with their proposed efforts to investigate the mechanism of Li transport, make up a good plan. The reviewer encouraged the team to test multiple cathode materials and different cathode compositions with varying porosity to take advantage of their in situ polymerization approach. Additionally, the team needs to demonstrate results on Li-dendrite growth suppression with their best performing electrolytes.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer remarked that the work is highly relevant. Solid electrolytes are considered promising materials candidates to eliminate dendritic growth in Li-metal anode batteries.

Reviewer 2:

The reviewer commented that the research is relevant to the DOE efforts in developing safer, high energy density, high power density, solid-state batteries with metallic Li anodes. This project addresses development of highly conducting and mechanically stable, solid-composite electrolytes.

Reviewer 3:

The reviewer indicated that this project strongly supports the overall DOE objectives.

Reviewer 4:

The reviewer said that SSEs are an important focus for DOE VTO.

Reviewer 5:

According to the reviewer, the future success of solid-state batteries critically depends on the discovery and fabrication of solid electrolytes. Exploring solid electrolytes based on a composite polymer with inorganic polymers is a great idea; a similar principle has been demonstrated for the case of oxygen-ionic conductors.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the team has sufficient resources to successfully meet the milestones.

Reviewer 2:

The reviewer said that the resources on this project are sufficient to achieve the stated milestones.

Reviewer 3:

The reviewer remarked that the resources are adequate for the proposed research.

Reviewer 4:
The reviewer commented that the resources available for the team are adequate.

Reviewer 5:
The reviewer observed that the resources are adequate.

Presentation Number: bat322
Presentation Title: High Conductivity and Flexible Hybrid Solid-State Electrolyte
Principal Investigator: Eric Wachsman (University of Maryland)

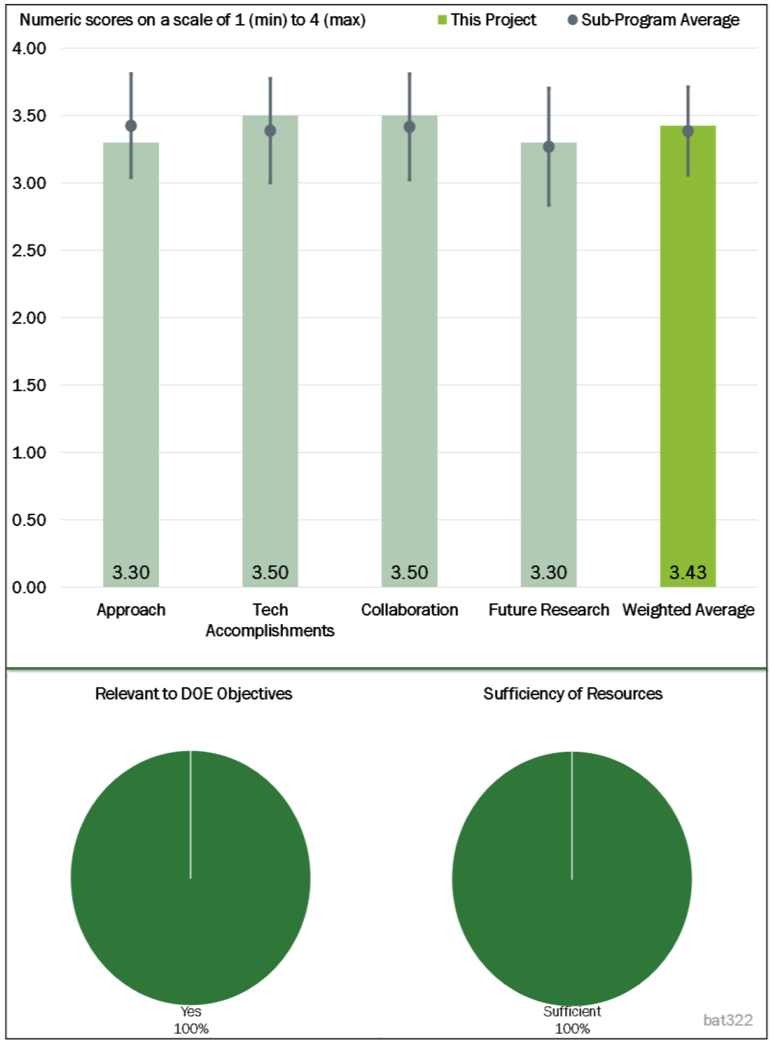

Figure 2-38 - Presentation Number: bat322 Presentation Title: High Conductivity and Flexible Hybrid Solid-State Electrolyte Principal Investigator: Eric Wachsman (University of Maryland)

Presenter

Eric Wachsman, University of Maryland

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the approach in this project involves fabricating a hybrid solid electrolyte based on a polymer matrix and inorganic garnet fibers, with high ionic conductivity and mechanical robustness. The choice of garnet structures for inorganic fibers is highly promising, as this class of materials shows high performance as solid electrolytes. The reviewer praised the combined modeling and experimental approach to characterize Li-ion diffusion, mechanical properties, and a potential of the developed hybrid SSE to suppress lithium-dendrite growth as excellent.

Reviewer 2:

The reviewer said that the team employed a combined experimental/computational approach to developing a solid, flexible electrolyte to enable high-performance Li-ion batteries with the goal of achieving an energy density of 450 Wh/kg. The team has developed a garnet textile-reinforced, hybrid composite-polymer electrolyte. The project started in 2016 and has made remarkable progress in addressing the technical barriers.

Reviewer 3:

The reviewer remarked that this project aims to develop composite solid electrolytes based on polymer and garnet fibers. The approach is to integrate experimental with computational modeling. The reviewer stated that the computational predicated results are very interesting; the team could use this modeling result to guide the designing of better materials. Typically, it appears that the surface and grain boundary will play a big rule in contributing to ionic conduction. Therefore, the reviewer said that the work can be further extended to modify the interface and grain boundary to get better ionic conduction.

Reviewer 4:
The reviewer noted that solid-state anode development is critical to meet specific energy, energy density, cost, and life goals. So, the approach is well defined for the technical solutions.

Reviewer 5:
The reviewer observed that the project addresses the ability of taking a typically rigid SSE (garnet) and making it flexible by combining it with another polymer-based electrolyte and providing unique processing to enhance conductivity through the layer. The reviewer had reservations about this approach: by utilizing a hybrid electrolyte, the project is addressing one issue but creating many more due to all the known problems with PEO.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer noted that the characterization and building of the electrolyte film are on target.

Reviewer 2:
Based upon the goals of the project, the reviewer reported that the PI has definitely achieved the targets, although this would not be a real-world solution due to the issues with PEO.

Reviewer 3:
The reviewer indicated that the team made great progress in fabricating the flexible hybrid electrolyte. At the same time, computation results are excellent, which provide key insights regarding the factors that may affect the ionic conduction. It should be beneficial if the team can use the modeling results to guide the design of a new composite structure for optimization of ionic conduction. Therefore, the present reviewer suggests a better integration of experiments with modeling.

Reviewer 4:
The reviewer stated that the team has demonstrated several technical accomplishments and progress in the overall project. The project is in good shape in terms of milestones. The team has not reported much in terms of mechanics of such flexible solid electrolytes. The reviewer suggested that tensile and penetration/puncture tests be carried out on the developed electrolytes.

Reviewer 5:
The reviewer summarized the progress by stating that the team demonstrated successful preparation and characterization of garnet fibers, as well as processing of the prepared fibers into a garnet textile and used garnet fibers to fabricate a hybrid composite polymer electrolyte. The team demonstrated that Li-ion conductivity of the hybrid solid electrolyte is dominated by the Li transport through the garnet fibers rather than polymer matrix. The synthesized-polymer, garnet-fiber hybrid electrolyte demonstrated good conductive and mechanical properties. The reviewer noted that hybrid SSEs with a thickness of 20 microns was fabricated using a hot press, meeting one of the goals of the proposed research. The computational study on Li-dendrite growth in the cells containing the developed hybrid SSE with garnet fibers revealed not only the effect of the presence of the fibers in the polymer matrix but also demonstrated how defect chemistry in garnet can affect formation of lithium dendrites. These results are important for both finding the best polymer matrix/inorganic fibers ratio and optimizing garnet-fiber chemistry to achieve the best hybrid solid-electrolyte performance.

The reviewer pointed out that it would be desirable to know the details of the chemistry of the polymer component of the hybrid solid electrolyte as well as the role of the polymer matrix in the overall performance of the hybrid electrolyte, such as ionic conductivity, mechanical robustness, and suppression of Li dendrites growth. The reviewer encouraged the development of the hybrid electrolyte with the fraction of the fibers oriented perpendicular to the electrode because the project showed that Li transport is dominated by Li diffusion through inorganic fibers. Development of the hybrid solid electrolyte with such architecture would maximize ionic conductivity. However, for mechanical robustness, a fraction of the fibers need to be oriented parallel to the electrodes. The reviewer thought it would be exciting to see a study on controlling the ratio of fibers oriented parallel and perpendicular to the electrodes with an evaluation of their Li-ion conductivity and mechanical strength. Such a study would be very novel and potentially impactful.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the team has a good background, understanding, and phenomenal resources to make innovative solutions for solid-state batteries.

Reviewer 2:

The reviewer found the collaboration with the researchers to be good.

Reviewer 3:

The reviewer mentioned that the team consists of three PIs with complementary expertise and there is excellent coordination among team members, all located at the same university. Professor Wachsman focuses on the experimental development of the garnet fibers with optimized ion conductivity and mechanical strength, Professor Mo provides computational predictions of mechanical and conductive properties, and Professor Hu develops hybrid electrolytes and characterizes full cells with the best performing hybrid SSE. In addition, the team partners with Professor Thangadurai, co-inventor of garnet fibers, whose vision and consultation might be helpful for the performable project. Information on the team publications was not provided, making it difficult to evaluate the status of collaborative publications.

Reviewer 4:

While the team is composed of three parties within the University of Maryland and one external collaborator, the reviewer suggested that it would be beneficial to extend the collaboration to other groups. One potential collaborator will be Professor Wu from West Virginia University, who is working on a BMR project with a similar concept of making composite electrolytes of polymers and inorganic materials.

Reviewer 5:

The reviewer said that the team has demonstrated several good collaborations in experimental synthesis and characterization and modeling. More collaborations are needed to study the mechanics of the developed electrolytes (tensile and penetration tests).

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the future plan is to do more testing on the structure and integrate it into a non-symmetrical cell. This is very relevant and will uncover many of the integration issues that were previously discussed; in addition, this will provide the research team a chance to produce another innovative solution.

Reviewer 2:

According to the reviewer, the future research will be focused on the experimental characterization of the Li-dendrite growth in the cells containing the developed hybrid SSE with garnet fibers and the development of the full Li-sulfur cells with an energy density of 450 Wh/kg.

Reviewer 3:

The reviewer saw the future research as very well focused.

Reviewer 4:
The reviewer said that the proposed research appears to have specific objectives: one is modeling and the other is experimental. The reviewer perceived that a close integration of modeling results with experiments is missing.

Reviewer 5:
The reviewer commented that the proposed future work is well planned and suggested that the team study the mechanical property changes during and after cycling.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer found the research to be relevant to the DOE efforts in developing safer, high-energy density, high-power density, solid-state batteries with metallic Li anodes, including Li-sulfur batteries that can be processed within the existing battery-manufacturing infrastructure. This project particularly addresses the development of highly conducting and mechanically stable solid-composite electrolytes.

Reviewer 2:
The reviewer said that the solid-state hybrid electrolyte will meet DOE energy targets and will reduce costs.

Reviewer 3:
The reviewer remarked that the proposed research is relevant to the DOE objective of developing better batteries for the next-generation electric car. One of the barriers is the solid electrolyte, and this research topic just serves this topic.

Reviewer 4:
The reviewer noted that high-performance, flexible solid electrolytes are greatly needed for the next-generation batteries. There are several challenges, such as chemical stability, mechanical robustness, and compatibility between the solid electrolyte and the electrode that are less or completely unknown. The project is timely and of great interest.

Reviewer 5:
The reviewer affirmed that to enable the use of garnet-based electrolytes utilizing traditional low-cost processing, an ability to make them flexible and rollable must be developed.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that $1.4 million should be able to support the work described in the project.

Reviewer 2:
The reviewer mentioned that three PIs have fully used the resources (experimental and computational facilities) at the University of Maryland and the University of Calgary (collaborator).

Reviewer 3:
The reviewer said that the current resources are sufficient to achieve the project goals.

Reviewer 4:
The review commented that the resources available for the team are adequate.

Reviewer 5:
The reviewer stated that the resources are sufficient for the proposed research.

Presentation Number: bat323
Presentation Title: Self-Forming Thin Interphases and Electrodes Enabling 3-D Structured High Energy Density Batteries
Principal Investigator: Glenn Amatucci (Rutgers University)

Presenter
Glenn Amatucci, Rutgers University

Reviewer Sample Size
A total of five reviewers evaluated this project.

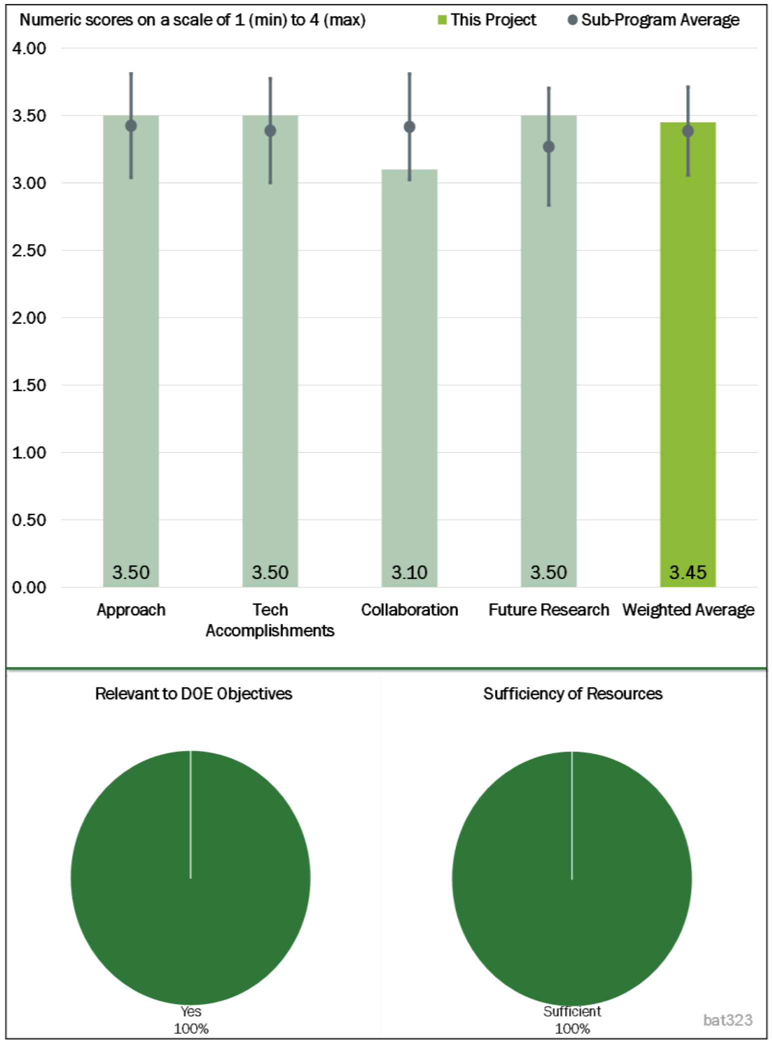

Figure 2-39 - Presentation Number: bat323 Presentation Title: Self-Forming Thin Interphases and Electrodes Enabling 3-D Structured High Energy Density Batteries Principal Investigator: Glenn Amatucci (Rutgers University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
According to the reviewer, the development/optimization of positive/negative reactive current collector, bi-ion conductor, and battery engineering and design are the keys to developing and implementing the Li-metal-based, metal-fluoride battery. The project is well designed and feasible. It addresses composition and scalable fabrication along with composition and microstructure to facilitate rapid and uniform Li deposition during the formation cycle and subsequent cycling. It also addresses a lithium-fluoride--based composition to enable facile electrolytic decomposition at the interface that will release the F^- and Li^+ ions to react with the positive and negative current collectors respectively, thereby forming the cell in situ while maintaining a fast ionic conductor of Li^+ to facilitate subsequent cycles. In a word, most barriers are addressed based on the designed approach.

Reviewer 2:
The reviewer commented that the team developed and successfully utilizes an elegant approach to fabricate a 3-D structured, high-energy battery through a self-forming process using a bi-ion solid-state conductor comprised of a Li-fluoride-based nanocomposite glass. This bi-ion conductor releases fluorine and Li ions that react with positive and negative current collectors forming the electrodes, while the remaining fraction of the bi-ion conductor serves as a solid electrolyte. The anode in this electrochemical system is metallic Li. The cathode chemistry enables versatility through the formation of metal fluorides exhibiting high energy density, conversion-type electrochemistry due to the possibility of reacting with more than one Li ion during battery operation.

Reviewer 3:

The reviewer found this to be a good approach to developing a self-forming, solid-state battery. The chemistry is very challenging, very high risk, and high reward, which is what DOE should be funding.

Reviewer 4:

The reviewer noted that this project aims to develop and optimize the cell through the following three approaches: A nanolayered structured positive current collector, a negative current collector that enables high efficiency Li plating and stripping, and bi-ion Li-fluoride-based conductors. This project provides a well-designed approach to address the transport barriers, low utilization of a positive reactive current collector, and low efficiency of Li plating and stripping the negative current collector to achieve high energy density. It will be good if characterization tools are included.

Reviewer 5:

It was not exactly clear to the reviewer what the PI is trying to do. The chemistry is never completely mapped out nor were the specific challenges of that chemistry explained. Perhaps everything the team is doing falls under "intellectual property," but it is hard to review this work with only a vague sense of what the team is trying to accomplish.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer enthused about the wonderful progress that has been made in this project, including increasing the energy density from 25 Wh/l to greater than 570 Wh/l, the positive reactive current collector utilization from 1% to greater than 60%, and the rates in the C/2-C/20 range by two orders of magnitude The capacities and capacity retention also show great improvements.

In this project, the reviewer noted that the electrolytic method is used to form a solid-state rechargeable battery and the bi-ion Li-fluoride-based conductor. The presented in situ method is really facile, and it can bring substantial progress in the reactive current collector, which increases the efficiency for the negative current collector according to the results achieved in FY 2017. The reviewer mentioned that the project achieved a dramatically increased energy density from 25 Wh/l to more than 570 Wh/l, and the positive reactive current collector utilization improved from 1% to more than 60%. Also, improved capacity retention has been achieved. There has been substantial progress in realizing the key technical accomplishments, including the scalable processing.

Reviewer 2:

Although the progress to date seems modest, the reviewer commented that it is extremely good considering the difficulty in getting a solid-state battery using an iron fluoride-based cathode to work at all.

Reviewer 3:

The reviewer reported that the team demonstrated greater than 60% utilization of the cathode current collector to form active metal fluoride cathodes, which excellently meets their objective to utilize more than 50% of the cathode current collector. Ionic conductivity of the solid lithium-fluoride-based electrolyte sandwiched between the cathode and anode post-battery formation showed Li conductivity on the order of 10^{-4} S/cm, which is seven orders of magnitude higher than that of pure Li fluoride, and is also considered as good conductivity for the solid electrolytes. This result enabled the team to achieve rates in the C/2 – C/20 range, significantly higher than before. The team demonstrated energy density of more than 570 Wh/l, bringing the team closer to the goal of 1,000 Wh/l. The reviewer explained that more detailed electrochemical characterization with a graph demonstrating battery-cycle life, rate capability, impedance, etc., is desirable.

Reviewer 4:

The reviewer observed that a unique deposition system for the hybridization and fabrication of multicomponent nanolayered architectures has been designed, which has enabled the control of conductivity type and amount of transport pathways, leading to the utilization improvement of greater than 60%. Hybridization of transport pathways made the current density increase by one order of magnitude leading to the discharge rate of more than C/10. A cost-effective, scalable manufacturing process has been developed to reduce the cost. The self-formed cell stack had energy densities of greater than 500 Wh/l and 200 Wh/kg at a rate of at least C/10. Although the research team has not reached the target of a self-formed cell stack with energy densities of at least 1,000 Wh/l and 300 Wh/kg at a rate of C/10 and utilization improvement of more than 75%, they are on the right track to reach the goal. The reviewer suggested that the PI include the performance data of the battery being developed. For example, the reviewer wants to know what the ionic conductivity and electrochemical window of the Li-fluoride electrolyte are.

Reviewer 5:

The reviewer commented that the team has clearly made progress, but without knowing exactly what the team is doing, it is hard to say if this progress is fantastic or poor. If it is poor, then the reviewer said that the team has finally caught up to where everyone else is.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that it is mostly a team of one. The team appears to be making progress so the reviewer assumed some progress is a result of effective collaboration.

Reviewer 2:

The reviewer said that all the work was performed at Rutgers University.

Reviewer 3:

The reviewer commented that there are essentially no active collaborators to date, which is probably appropriate given how early and high risk this project is. The reviewer did not see this as a concern yet.

Reviewer 4:

The reviewer noted that all work has been performed at Rutgers University; the team needs to strengthen the collaborations to accomplish this project with more efficiency.

Reviewer 5:

The reviewer pointed out that the team of researchers, led by Professor Amatucci, is all located at Rutgers University and benefits from the close proximity enabling tight collaboration. Information on the team publications was not provided, making it difficult to evaluate the status of collaborative publications.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer called the plan to improve and optimize all of the components of their battery fantastic.

Reviewer 2:

The reviewer stated that the proposed future research includes four parts, concentrating on the negative current collector, cell utilization, cell stability, and cell design, which will greatly improve the performance of the designed batteries. It is important and reasonable to continue the project. The reviewer said that the plans proposed for future research on Slide 17 are well designed and focused on the research targets. There are some specific numerical targets (described in the FY 2019 schedule) that can be judged in the future.

Reviewer 3:

The reviewer noted that the future research will be focused on achieving reversible and efficient Li-metal deposition stripping at the anode side of the battery, achieving electrochemical and mechanical stability during battery cycling, and designing and optimizing the cell architecture to achieve target parameters of energy densities of more than 1,000 Wh/l and more than 400 Wh/kg at 12 within one battery unit. The team seems to be on a good track to achieving their goals.

Reviewer 4:

The reviewer commented that to reach the proposed energy densities of more than 1,000 Wh/l and greater than 400 Wh/kg at 12V within one planar unit, the research team planned their future work in a logical manner. The team will optimize the composition and microstructure to enable high-efficiency Li stripping and plating of the negative current collector, improve the cell utilization during in situ formation of the initial amount of reactive current collector, and enhance cell stability. The proposed future work will help to achieve the final target.

Reviewer 5:

The reviewer pronounced that future work to be reasonable.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer believed that the team is working on a Li-iron fluoride system by developing a compatible solid electrolyte that prevents dendrite growth and promotes uniform Li deposition and a cathode that can be cycled. This would be a very low-cost, high-energy system if the team is successful.

Reviewer 2:

The reviewer indicated that this project focuses on self-forming thin interphases and electrodes enabling 3-D structured high-energy density batteries. The reviewer enumerated the reasons for the research strongly being consistent with DOE objectives: The weight and volume energy density targets of 350 Wh/kg and 750 Wh/l at a cell level, respectively; the necessary improvements under routine and extreme operating conditions; and achieving cost-effective methods, which is very important.

Reviewer 3:

The reviewer found that the combination of a conversion cathode and metallic Li anode addresses one of the DOE targets to achieve a high-energy density, electrochemical energy-storage system. The process of battery fabrication through a self-forming process is easy and efficient. The team utilizes low-cost materials.

Reviewer 4:

The reviewer affirmed that the project will facilitate the realization of DOE’s goals.

Reviewer 5:

The reviewer indicated that it is yet to be seen if a solid-state cell can provide the power needed for EV operation. But, the reviewer opined that it is worth pursuing given the huge advantages of solid-state cell design.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

All the synthesis and characterization resources for this project are sufficient, according to the reviewer.

Reviewer 2:

The reviewer said that the resources available for the team are adequate.

Reviewer 3:

The reviewer found the resources to be reasonable.

Reviewer 4:

The reviewer pointed out that no more facilities will be needed according to the previous work and proposed future research. Therefore, resources are sufficient to support the cost of raw materials, further testing, and Ph.D. students or a postdoctoral researcher.

Reviewer 5:

The reviewer suggested that the team is going to need a lot more time and money to make this system work, if it is possible at all. What they are receiving now is probably the correct amount until significant progress is made or a clear indication that progress is possible.

Presentation Number: bat326
Presentation Title: Self-Assembling and Self-Healing Rechargeable Lithium Batteries
Principal Investigator: Yet-Ming Chiang (Massachusetts Institute of Technology)

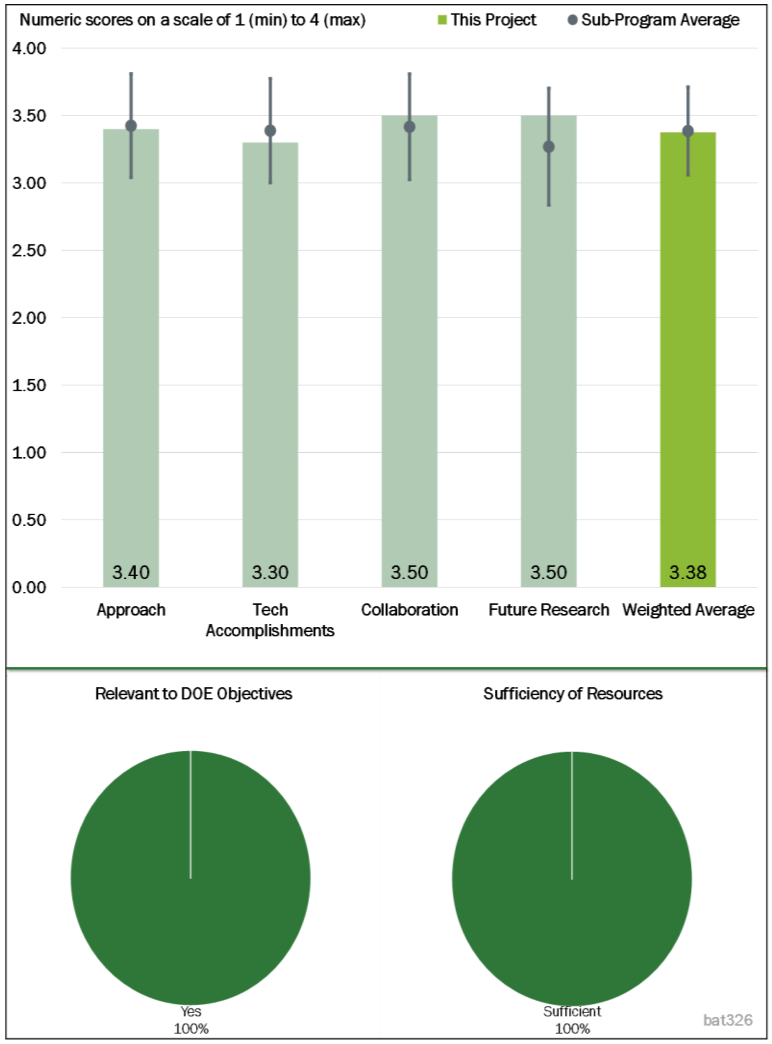

Figure 2-40 - Presentation Number: bat326 Presentation Title: Self-Assembling and Self-Healing Rechargeable Lithium Batteries Principal Investigator: Yet-Ming Chiang (Massachusetts Institute of Technology)

Presenter

Yet-Ming Chiang, Massachusetts Institute of Technology

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the project team first performed a DFT calculation to identify and downselect self-forming and self-healing halogenated additives as it is effective to overcome most barriers. According to the DFT calculation, the team found the possibility of protecting the Li-metal anode by simply adding halogenated additives (FEC). However, according to the reviewer, the DFT calculation just declares that the decomposition reaction is reasonable in thermodynamics. Another significant aspect is whether it is reliable in dynamics. Then, the experimental matrix, which is an efficient way to explorer the influence of different parameters at the same time, was conducted and the impressive result was achieved. Besides, the battery test methods are credible to educe the result. So, the reviewer pronounced the approach to be efficient to solve the barriers.

Reviewer 2:

The reviewer said that there was a good approach to searching for testing self-forming protective layers to enable Li-metal anodes.

Reviewer 3:

The reviewer commented that the approach explored by the team is focused on discovering electrolyte formulations, including solvents, salts, and additives that would enable the formation of highly Li-ion conducting, mechanically robust, SEIs that are self-formed and exhibit self-healing properties. The additives selected belong to the class of halides and halogenated compounds, building on successful implementation of FEC. The reviewer stated that the goal is to enrich the SEI with Li fluoride to obtain a dense film and decrease the size of organic moieties in the SEI. Utilization of metallic Li as an anode protected by the formed SEI offers an opportunity to enable high-energy density batteries.

Reviewer 4:

For now, it appeared to the reviewer that adding a fluorinated solvent will yield Li fluoride on the surface. The reviewer was not sure of the value of DFT to predict this.

Reviewer 5:

In this project, the reviewer noted that theory calculation and experiments are performed to find a solution to prevent Li-dendrite formation. The team used DFT to downselect the self-forming and self-healing halogenated additives. The team used a lot of characterization tools to investigate the morphology, chemical structure, and electrochemical performance of the assembled cell to demonstrate that halide additives can effectively diminish Li-dendrite formation. According to the reviewer, it would be good to clarify why formation of a Li-fluoride layer on the anode can prevent from the formation of Li dendrites. It is better, the reviewer opined, to compare the current approach with other reported methods for the formation of Li dendrites

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

According to the reviewer, the research team has integrated theory, calculations, and experiments to select the halide additives in the electrolyte to change the morphology (less dendritic) and compactness (denser) of the deposited Li. The cycling performance of the resulting full cell is improved by the addition of fluorinated solvent into the electrolytes. Although last year's milestone has not been met yet, the progress is on track to achieve their overall objective.

Reviewer 2:

In terms of technical accomplishments, the reviewer reported that the project team had developed a new approach to measuring Coulombic efficiency (CE) that deserves further consideration. The new approach shows in the formula,

$E_{average} = 1 - Q_D/nQ_T$ where Q_D equals the total Li capacity of $Q_D = Q_T + Q_{excess}$,

Q_T equals the cycling of lithium capacity (3 mAh/cm^2 in these tests), and n equals the number of deposition/stripping cycles when there is a sudden and significant increase in (over)potential for Li stripping. The reviewer commented that the team left Q_{excess} undefined. The formula is valid for only the end of cycling when the cell is out of operation. This is forbidden in commercial use. The reviewer found that it is difficult to understand the physical significance. The formula can be written as $E_{average} = 1 - 1/n - Q_{excess}/n * 1/Q_T$, and the meaning of the subtrahend is confusing.

In respect to process, 5 of 7 quarters have been completed in 15 months with 19 months left. About half of time-consuming parts have been completed, so this reviewer commented that the project is on schedule.

Reviewer 3:

The reviewer pointed out that the team has developed a new Li-Li asymmetric cell with one Li electrode being only 20-microns thick and the other Li electrode being much thicker. Such cells enable a clear evidence for the end of the test identified by the dendritic Li plating. Moreover, the team suggested a refined way to calculate CE. Once these results are published, the reviewer recommended that the community consider adopting approaches developed by this team to become a standard way of metallic Li-anode characterization. The team demonstrated that the addition of halide additives improves morphology of the plated Li with less pronounced Li-dendrite growth compared to the cells without the additives. The cells with the additives were cycled longer than the ones without the halide additives. The reviewer observed that improved CE was demonstrated in the course of the systematic study of exploring different fluorinated solvents and additives. Although the team did not reveal the actual chemistry of the solvents and additives, the team found that di-fluorides are better than mono-fluorides, and cycling organic molecules are better than linear ones.

The reviewer indicated that the team showed an intriguing result in which the cell containing the $LiPF_6$-fluorinated solvent electrolyte (Cell 1) showed not only better stability over the course of battery cycling compared to the cell containing $LiPF_6$ ethylene carbonate-dimethyl carbonate (EC-DMC) (50/50) electrolyte (Cell 2), but also less drastic capacity fading. After 100 cycles, Cell 1 still exhibited relatively a stable 50 mAh/g, while Cell 2 showed only 10 mAh/g. The reviewer encouraged the team to analyze Li-anode post-cycling in the case of both cells. The reviewer wondered if there are islands/areas of non-dead protected Li in the case of the Cell 1, which still work well to enable this capacity. The self-healing properties of the formed SEI remained unclear to the reviewer, who encouraged the team to provide more details and characterization of the self-healing SEI.

Reviewer 4:

The reviewer remarked that the team built symmetric cells and full cells and demonstrated that there are more cycles when a fluorinated solvent is added, apparently due to the formation of lithium fluoride. Unfortunately, the reviewer opined that the CE is still way too low to be relevant.

Reviewer 5:

The reviewer found a very good improvement in the symmetric cell cycling shown, but improved cycling from 40 cycles to 70 cycles in the Li/LCO full-cell using fluoride additives. The reviewer commented that 70 cycles in a full cell is not particularly good. The Battery 500 Consortium recently showed over 200 cycles with a lean electrolyte and thin Li metal. If this poor cycling is due to poor CE, which is most likely, then the reviewer suggested that that is what needs attention. The reviewer asked if the halides improve CE, and if so, there were no data to that effect.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, the team benefits from the complementary expertise of the PI and co-PI, with Professor Chiang contributing experimental efforts and Professor Viswanathan focusing on theoretical predictions. Together, the PI and co-PI comprise a strong team. Additionally, the team collaborates with 24M Technologies, a company that is funded through an Advanced Research Projects Agency–Energy Ionics project, and the team supplies their best performing electrolytes to 24M. The reviewer noted that the team published two articles and submitted one patent application. With the results accomplished, the team should be able to demonstrate better productivity in the remaining project time.

Reviewer 2:

The reviewer said that the team has found an outside source for Li and plans on using the same source to build large cells.

Reviewer 3:

The reviewer stated that the only collaborator is 24M Technologies, which may be sufficient considering how early stage this R&D is.

Reviewer 4:

The reviewer indicated that the team has finished its collaboration with the 24M Technologies; .by receiving thin Li-metal foils, the team can do a better test.

Reviewer 5:

The reviewer remarked that the team has received thin Li-metal foils for experiments from 24M Technologies and plans to prepare and test 18 cm^2/80 cm^2 pouch cells in the future. The quality of Li-metal foils and the pouch-cell assembling technology are essential for experiments. In this project, the reviewer advised that the team needs to strengthen collaborations to accomplish this project with more efficiency.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the future work will be focused on overcoming the remaining barriers, which include suppressing Li-dendrite growth effectively and reproducibly, identifying new halide additives to further improve CE, fabricating the cells with greater than 10 mAh capacity, and developing Li-ion cells cycling at greater than 5 mAh/cm^2 at C/5 over 100 cycles.

Reviewer 2:

The reviewer stated that the team plans theoretical identification and quantification of better fluorinated solvents for self-formation and self-healing to improve the cycling performance and suppress the Li dendrites. The proposed research is to address the key issue of Li-metal anodes and will help to build very high energy density (more than 350 Wh/kg), rechargeable Li batteries. The team will also focus on the structural and chemical characterization of the Li-metal surface with different fluorinated solvents in the future work, which will help to establish quantitative criteria for effectiveness and reproducibility in dendrite suppression.

Reviewer 3:

According to the reviewer, the team proposed to find better fluorinated solvents for self-formation and self-healing; conduct structural and chemical characterization of Li-metal surface with different stages of cycle life; further develop an asymmetric Li-lithium cell cycling methodology to resolve CE at different stages of cycle life; demonstrate Li-Li asymmetric cells that meet established criteria cycling at $\geq$ 3 mAh/cm^2 at C/5 rate over 30 cycles; and operate Li-NMC full cells with high areal capacity of more than 3 mAh/cm^2 for more than 100 cycles.

The reviewer proposed that further study on better fluorinated solvents and the relative structural and chemical evolution on the Li-metal surface are very much necessary to understand the mechanism of fluorinated solvents. To commercialize this research, the reviewer said that higher areal capacity of $\geq$3 mAh/cm^2 Li-NMC full cells is the first step, and achieving the asymmetric Li-lithium cell $\geq$3 m h/cm^2 is the first efficient method. However, the concentration of fluorinated solvents is also a notable problem to understand the influence of fluorinated solvents.

Reviewer 4:

The reviewer commented that the team plans to use DFT to discover additional solvents. It was not clear to the reviewer as to what properties the team would like the SEI to have other than Li fluoride.

Reviewer 5:

The reviewer said if the poor full cell cycling is due to low CE, then that is what needs attention. The reviewer asked if the halides improve CE, as there were no data about that.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer commented that the purpose of this project is to suppress the dendrite growth on the surface of Li-metal, enabling a very high energy density (greater than 350 Wh/kg), rechargeable Li battery to improve the driving range and reduce the cost for electric vehicles. This project meets the mission of DOE to ensure America's prosperity by addressing its energy at this point. A Li-metal anode is a promising anode material with ultrahigh energy density and low potential. According to the reviewer, the lower the potential anode is, the higher voltage full cells are and the higher power density full cells are. A Li-metal anode is one of a few materials that show high specific capacity and low potential in the same time. However, the reviewer pointed out that the emergent issue is to solve the safety problem that arises from the dendrite growth on the surface of Li-metal. Therefore, the project supports the overall DOE objectives.

Reviewer 2:

The reviewer remarked that the project explores the protective properties of Li-halide films on Li-metal anodes and aims at demonstrating self-assembling/self-healing batteries. In addition to developing a simple and scalable self-forming battery fabrication process, utilizing metallic Li as an anode offers an opportunity to reach high energy density (greater than 350 Wh/kg), which is sought for powering EVs and making EVs a more affordable means of transportation. The reviewer agreed that these goals are in line with the DOE targets.

Reviewer 3:

The reviewer affirmed that the self-formed Li-halide based solid-electrolyte interface could improve the cyclic performance of batteries and extend the lifetime of batteries.

Reviewer 4:

The reviewer opined that trying to get Li to work is consistent with trying to get to higher energy density.

Reviewer 5:

The reviewer stated that enabling Li-metal anodes is clearly very relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the project team mainly explored electrochemical formation of Li-halide based solid-electrolyte interfaces. The funding for 2018 is $462,912. The reviewer pointed out that no more facilities will be needed according to the previous work and proposed future research. Therefore, resources are sufficient to support the cost of raw materials, further testing, and Ph.D. students or a postdoctoral researcher.

Reviewer 2:

All the characterization, synthesis and theory calculation tools are sufficient to meet the milestone proposed in this project in time, according to the reviewer.

Reviewer 3:

The reviewer said that the resources are sufficient for this effort.

Reviewer 4:

The reviewer found the funding to be reasonable for this project.

Reviewer 5:

The reviewer commented that the resources available for the team are adequate.

Presentation Number: bat328
Presentation Title: Dendrite-Growth Morphology Modeling in Liquid and Solid Electrolytes
Principal Investigator: Yue Qi (Michigan State University)

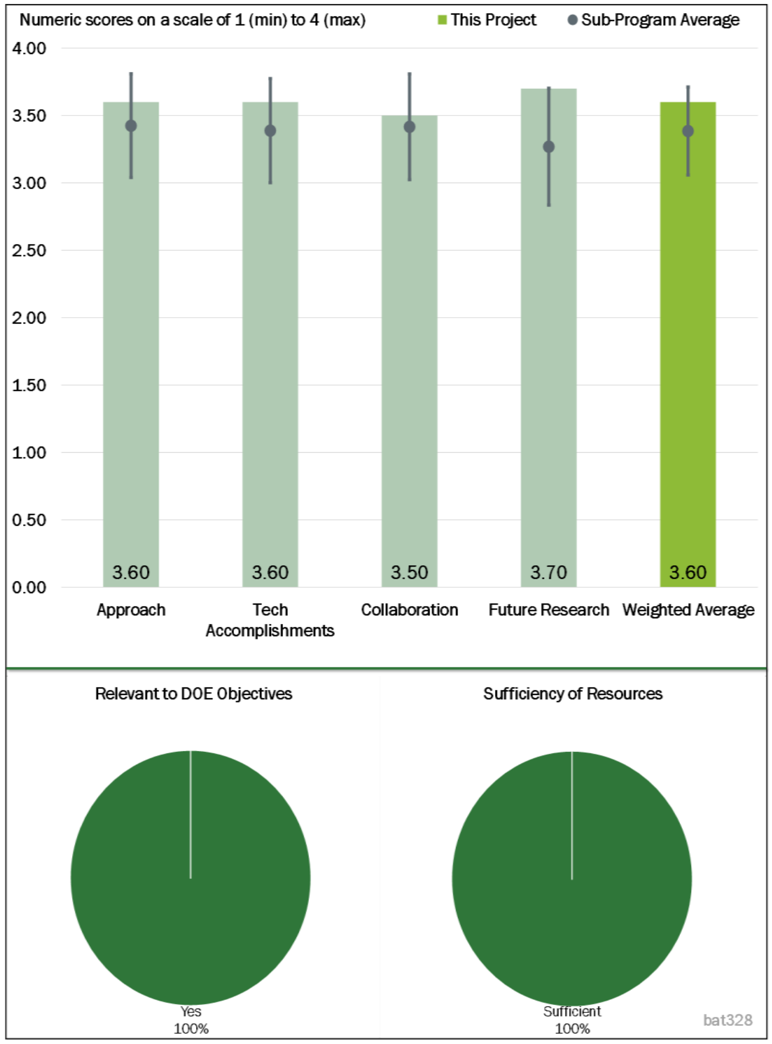

Figure 2-41 - Presentation Number: bat328 Presentation Title: Dendrite-Growth Morphology Modeling in Liquid and Solid Electrolytes Principal Investigator: Yue Qi (Michigan State University)

Presenter

Yue Qi, Michigan State University

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that this project utilizes a multiscale modeling and experimental approach, including a combination of micron-scale and atomic-scale modeling that is used to predict Li-dendrite nucleation and growth kinetics and morphology; the theoretical predictions are validated through experimental investigations. The results from this project, according to the reviewer, can help to accelerate the adoption of Li-metal electrodes in current and emerging battery technologies. In parallel, new computational models suitable for the computational characterization of Li-metal anode and solid-electrolyte interface have been developed and potentially can be universally applied to other meta-anode systems.

Reviewer 2:

The reviewer liked the methodical approach of going after this problem from many angles.

Reviewer 3:

The reviewer commented that this was a good approach to trying to uncover more clues about the growth of dendrites in both solid- and liquid-electrolyte cells.

Reviewer 4:

The reviewer stated that the project aims to simulate Li-dendrite evolution on the Li-metal anode side through multiscale modeling and an experimental approach along with micron-scale, phase-field models and atomic-scale, DFT-based simulations. The reviewer said that the modeling could be used to predict the Li-dendrite nucleation, growth kinetics, and morphology. The project used microscale experiments to observe the morphology of dendrites. The project is well designed and feasible.

The reviewer wondered whether the model to be developed will predict the critical factors that govern the nucleation and growth of Li dendrites. According to the reviewer, the PIs need to clarify what the criteria are for designing the surface coating on the Li-metal anode that can suppress the Li-dendrite formation.

Reviewer 5:

The reviewer indicated that the project led by Professor Yue Qi focuses on dendrite-growth morphology modeling in liquid and solid electrolytes. An efficient model was carried out to design the desired properties of artificial SEI coatings, the microstructure of solid-electrolyte materials, and the corresponding battery-operating conditions to avoid dendrite growth during cycling. The reviewer characterized this project as having clear and viable research thoughts, which can provide further directions on designing durable and safe Li-anodes for high-energy density Li-rechargeable batteries.

However, the reviewer offered some comments on the approach of this project for consideration: Because the model plays a crucial role on the calculation results, it is important to know whether the selected models in liquid and solid electrolytes are reasonable for practical cells. The reviewer wanted to see a discussion of more application conditions. In addition, correlations between the calculated results and experimental results should be discussed as well as performing more experiments to confirm the results from models. The reviewer pointed out that the electrolyte also plays an important role in batteries and wanted to know more about the influence of different electrolytes on Li dendrites in the models. The reviewer asked what the biggest differences are on the dendrite-growth of Li anodes in liquid and solid electrolytes and the reasons that lead to this difference. For further practical applications based on understanding from the model, the reviewer suggested that more full cells and punch cells should be assembled for high-energy density Li-rechargeable batteries to meet the DOE target. Lastly, the reviewer asked to see a detailed budget for every year in order to decide whether the remaining funds can support further research.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented than an implicit multiscale dendrite-growth model has been developed, which shows that lowering the exchange current (I_0) is the most efficient method of Li-plating to achieve a smooth surface and experimentally tunes the I_0 via surface engineering. A new, explicit model was also constructed to simulate Li-dendrite formation and growth in solid electrolytes with microstructure and internal defects (pores). The team is now on the right track to develop a multiscale model to predict the evolution of Li-dendrite morphology.

Reviewer 2:

The reviewer found that there was very nice insight into the effect of I_0 on dendrite growth with experimental results presented to confirm those predictions.

Reviewer 3:

The reviewer noted that significant progress in many areas has been made.

Reviewer 4:

In this project report, the reviewer remarked that the current accomplishments of the project are interesting and important. In detail, an implicit multiscale dendrite growth model was developed to investigate Li plating under different conditions. In addition, a new, explicit model was constructed to simulate Li-dendrite formation and growth in solid electrolytes with microstructure and internal defects. The reviewer posited that this in-depth understanding can give further insight into Li-dendrite formation and growth and provides good directions on the design of Li anodes. But, the reviewer cautioned that the completed percentage is only 35%, and during the ongoing project, more complex models will take longer time. The reviewer questioned whether the goals of this project can be finished when the project reaches the deadline and asked for some strategies to be provided to make sure of the successful completion of this project.

Reviewer 5:

The reviewer summarized the project results by saying that theoretical models that could be used to compute charge transfer reactions, calculate energy barriers, and predict metal dendrites formation have been developed and successfully used. The energy barriers of Li-ion desolvation and Li-ion diffusion through the solid electrolyte interface were calculated and shown to vary with potential. The morphology of Li dendrites under varying electrochemical conditions was predicted and compared to the morphology of magnesium dendrites. The team showed that lowering the exchange current can lead to suppressed Li-dendrite growth. A coating was applied on the Li surface; however, so far no improvements have been shown. Li-mossy structures grew and cracks in coatings were observed. Lastly, ALD of a LiPON coating showed the potential to prevent metallic-Li nucleation.

The reviewer questioned the fact that, in the team's report, only two papers are shown as published, and three manuscripts submitted. With such a strong team, the reviewer said it is desirable to see more products. The reviewer queried whether controlling current density during battery operation, as suggested, is the most efficient way to control Li-dendrite formation. The reviewer pointed out that this is not practical for real battery operation. The reviewer said it is desirable to see more practical ways to suppress Li-dendrite growth. The researchers plan to investigate the effect of coatings and electrolyte additives, which can provide acceptable, practical ways to minimize or ideally eliminate formation of lithium dendrites.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that Yue Qi leads the project. The PI has established collaborations and coordination with other institutions. For example, Gary Rubloff from the University of Maryland applied an ALD LiPON coating, which has higher Li conductivity compared to typical SEI components. Katherine Jungjohann from SNL Albuquerque investigated the Li morphology using a sealed liquid cell for in situ STEM, and investigated the effects of artificial SEI coatings on morphology at nanometer scale. Yan Yao from the University of Houston compared Li and magnesium plating morphology. Jie Xiao from PNNL and the University of Arkansas investigated the effect of electrolyte additives and their role on SEI. These collaborators provided in-depth insights using experimental tests, which can further confirm and support the calculation results. The reviewer confirmed that this is very important to successfully complete this project.

Reviewer 2:

The reviewer stated that this project is performed through collaborations with the University of Maryland, SNL Albuquerque, the University of Houston and PNNL, and the University of Arkansas. The reviewer found the he collaborations to be very effective.

Reviewer 3:

The reviewer remarked that the project appears to make relationships and obtain assistance in critical areas where it is needed.

Reviewer 4:

The reviewer indicated that the team is led by Professor Qi, a leading computational scientist, who focuses on atomic simulations. Other members include Professor Chen, who contributes microstructure modeling, and Dr. Xiao and Dr. Lu, who provides experimental results on Li-dendrite formation. Other collaborators are Professor Rubloff (coatings using ALD), Dr. Jungjohann (in situ STEM), Professor Yao (experimental comparison of Li and magnesium plating morphology), and Professor Xiao (the effect of electrolyte additives and their role in SEI). Overall, this is a very strong team with complementary expertise covering all relevant areas, including both computational and experimental research. The reviewer indicated that it would be desirable though to see more collaborative publications from such a strong team.

Reviewer 5:
The reviewer viewed that it is fairly early in this R&D project to be too concerned about collaboration. The team has the expertise and facilities it needs.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
According to the reviewer, the proposed future research will be focused on modeling of the SEI and correlation of SEI properties with Li-dendrite morphology in a liquid electrolyte. Furthermore, electrochemical-mechanical-structural coupling effects in cells with solid electrolytes will be investigated to propose a mechanism of Li-dendrite formation. Theoretical predictions will be verified through experiments.

Reviewer 2:
The reviewer found the future work to be well conceived.

Reviewer 3:
The reviewer commented that, to gain full understanding of the SEI and Li-dendrite growth, the project will further correlate SEI properties with Li-dendrite morphology in a liquid electrolyte and capture the internal structures of SEI. The future work is logically planned, according to the reviewer. Through the modeling and experiments, jointly designed effective combinations of bulk solid electrolyte and surface coatings will improve the cycling efficiency and life of lithium-rechargeable batteries.

Reviewer 4:
The reviewer said that all future work looks relevant and well-focused. The reviewer was curious about where some of these parameters are coming from and asked if they can reproduce existing data, e.g., the current at which the transition occurs from mossy Li deposition to dendritic Li deposition. The reviewer encouraged the team to engage with the Battery 500 Consortium R&D teams.

Reviewer 5:
In this project report, the reviewer summarized some of the proposed future research as follows: Correlate SEI properties with Li-dendrite morphology in a liquid electrolyte; develop an explicit SEI dendrite-growth model to capture the internal structures of SEI; investigate the electrochemical-mechanical-structural coupling effects and explore the mechanism of Li-dendrite formation in solid electrolytes from a phase-field model; and modeling and experiments jointly designed in effective combinations to improve the cycling efficiency and life of Li-rechargeable batteries. The reviewer opined that this future research is highly desirable to give further directions for the design of highly durable and safe Li anodes. However, the reviewer asked for more details and possible risks to be provided and discussed rather than only the goals for every challenging research topic.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted that the project led by Professor Yue Qi focuses dendrite-growth morphology modeling in liquid and solid electrolytes to solve the issues of dendrite growth, low CE, short calendar, and cycle life in Li-metal film electrodes. The reviewer posited that the successful accomplishment of this project can enable the design of durable and safe Li anodes for high-energy density, Li rechargeable batteries that can meet the DOE target for EV applications of greater than 350 Wh/kg and less than $100/kWh use.

Reviewer 2:
The reviewer stated that this research addresses a challenge of developing high-energy density batteries utilizing a Li-metal anode, which is one of the DOE targets. Such batteries, if they meet safety and cost requirements, are attractive for application in EVs.

Reviewer 3:
The researcher affirmed that the research will provide an interesting modeling approach to understand Li-dendrite growth during cycling, which will accelerate the adoption of Li-metal electrodes in current and emerging battery technologies.

Reviewer 4:
The reviewer commented that understanding the mechanism for Li-dendrite growth is the key to stopping it.

Reviewer 5:
The reviewer stated that R&D into Li-metal anodes is highly relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer pronounced the resources for modeling, synthesis, and characterization for experiments to be sufficient to achieve the proposed project goals.

Reviewer 2:
The reviewer said that the resources available for the team are adequate.

Reviewer 3:
The reviewer remarked that this is a well-managed project.

Reviewer 4:
The reviewer had no issue with resources.

Reviewer 5:
The reviewer praised the leader of this project for having good collaborations and coordination with other institutions. These collaborations can greatly support the successful accomplishment of this project. But, the reviewer wanted to see some other sources of technical personnel and facilities to support this project. Ph.D. students and postdoctoral researchers should focus on this project in order to achieve successful accomplishment within the given time. In addition, more sources should be required to realize fast and exact computational simulations.

Presentation Number: bat329
Presentation Title: Understanding and Strategies for Controlled Interfacial Phenomena in Lithium-Ion Batteries and Beyond
Principal Investigator: Perla Balbuena (Texas A&M University)

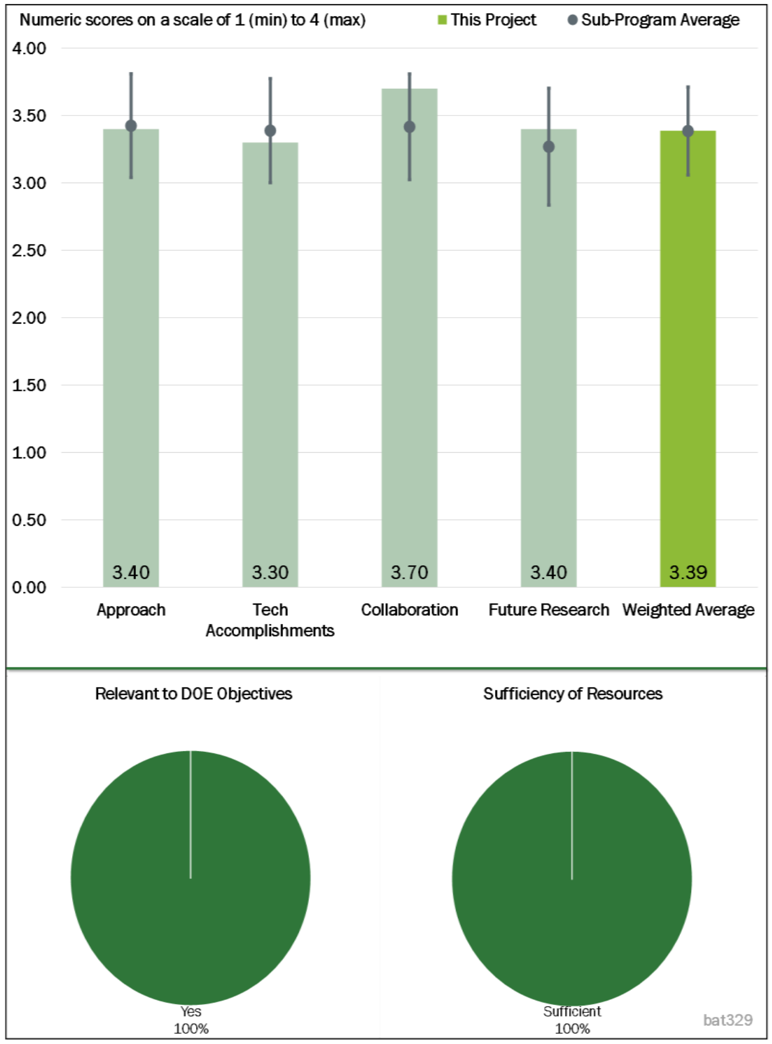

Figure 2-42 - Presentation Number: bat329 Presentation Title: Understanding and Strategies for Controlled Interfacial Phenomena in Lithium-Ion Batteries and Beyond Principal Investigator: Perla Balbuena (Texas A&M University)

Presenter

Perla Balbuena, Texas A&M University

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the project utilizes a multiscale modeling approach to elucidate parameters that impede extending the lifetimes of the Si and Li anodes. The project addresses such aspects as SEI formation, cracking of Si particles, and growth of Li dendrites. All findings obtained through theoretical predictions are compared with experimental results.

Reviewer 2:

The reviewer said that the project was a very nice and very challenging approach to investigating the character and structure of Li-metal and Si SEIs.

Reviewer 3:

The reviewer pronounced the project as an excellent, first-principles approach.

Reviewer 4:

The reviewer remarked that the project aims to address the interfacial issues that affect the lifetimes of the Si and Li-metal anodes by synergistic multiscale modeling. The modeling included the electronic structure and dynamics, the atomistic classical molecular dynamics, and the mesoscopic modeling. The modeling result is compared with the experimental evidence. The reviewer wondered if the modeling can predict the critical factors that form Li dendrites. The reviewer posited that it would be good if the calculation and simulation can predict and evaluate Li-dendrite nucleation and growth.

Reviewer 5:

In this project, the reviewer noted that synergistic multiscale modeling (ab initio, classical molecular dynamics, and mesoscopic level models), first-principles approach, and many other theoretical calculation approaches are applied to explore interfacial problems, such as SEI growth, Si-particle cracking due to volume expansion, Li-dendrite formation to address the barriers of loss of available capacity, and materials degradation during cycling and lifetime of the cell. These approaches can reveal the mechanism of the interfacial problems to a certain degree, and the reviewer suggested that the authors should consider whether the selected models in liquid electrolytes are reasonable for practical cells. Thus, more application conditions should be included. On the other hand, based on the calculation results, the reviewer proposed that more specific experimental strategies should be designed and provided to develop high-performance Si-/Li-anode materials, which will be more helpful to meet the targets.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that calculation and simulation results have identified the chemical origin of dendrite formation, the critical issue that leads to the loss of available capacity. The team elucidated the passivation role of the SEI layer on Li-metal. The team has completed the milestone. The result of SEI growth and multiscale characterization of dendrite growth are very interesting. Test and analysis of coatings for mitigation of dendrite growth are going on.

Reviewer 2:

The reviewer asserted that the project was a careful assessment of the relative rates of reduction of Li^+ in the presence of Li-metal as compared to other compounds that can compete for the electrons. It was also an investigation of preferential dendrite conditions.

Reviewer 3:

The reviewer praised the progress on Li-metal SEI and dendrite growth as good.

Reviewer 4:

The reviewer found intriguing computational results that showed differences for various electrolyte compositions in preferential reduction of Li or an electrolyte solvent molecule on the surface of a Li-metal anode. Additionally, the role of defects on the Li surface and the coating of the Li surface with molecules, typically found in SEI, towards Li reduction has been elucidated. These results are crucial for the understanding of Li-dendrite growth and developing ways to suppress Li-dendrite formation. The reviewer noted that modeling approaches have been developed to predict SEI growth and evolution, and a mesoscopic model of Li-dendrite growth revealed experimental conditions of electrochemical cycling that lead to different morphology of the plated Li. High overpotentials caused by high applied currents were found to promote Li-dendrite growth. The role of the Li-surface coating is being investigated through combined computational and microscopy characterization.

While this report contains multiple interesting results, it remained unclear to the reviewer what guidelines the computational approaches delivered for the experimental scientists. There were no explicit conclusions on the specific experimental parameters and how they need to be controlled to suppress Li-dendrite formation, mitigate the effect of Si cracking, or form the SEI that would lead to improved battery performance. The reviewer encouraged the team to state their conclusions and suggestions to the experimental scientists more clearly. The reviewer wanted to know the best Li surface, the best coatings (chemistry, thickness), the electrolyte formulations, and so on.

Reviewer 5:

In this project, the reviewer commented that technical accomplishments, such as identifying chemical origin of dendrite formation; elucidating the passivation role of SEI layer on Li-metal; initial studies of SEI growth; multiscale characterization of dendrite growth; and test and analysis of coatings for mitigation of dendrite growth on Li-metal have been realized. Some research papers have been published, which can give further insights into Li-dendrite formation and growth and provide good directions on the design of Li anodes.

However, the reviewer encouraged the team to consider more complex models, even knowing that this will take a longer time. Thus, the reviewer suggested that the authors should give a more detailed schedule to carry the program forward to finish on time. Additionally, these technical accomplishments are limited to theoretical calculations, and accomplishments on specific experimental strategies are lacking. Especially noteworthy is that there has been slow progress of research on a Si anode

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

In this project, the reviewer stated that there are many collaborations and coordination with other institutions. Contributors to a large part of the reported work are Professor Jorge Seminario, a co-PI from Texas A&M University (prime) on classical molecular dynamics (MD) and Professor Partha Mukherjee, a co-PI from Purdue University (sub-awardee on mesoscopic modeling). Y. Horowitz, Hui-Ling Han, and Gabor Somorjai from UCB contributed in the area of sum frequency generation vibrational spectroscopy together with ab-initio molecular dynamics simulations from Texas A&M University to characterize SEI formation at the surface of amorphous Si anodes. M. Vijayakumar from PNNL did experimental work while Texas A&M University did the theoretical characterization of electrolyte reduction over Li-metal surfaces covered by selected SEI components. Professor Shahbazian-Yassar from the University of Illinois at Chicago examined graphene-oxide coated materials as protection for copper current collectors where Li is plated along with characterization of surface science techniques of surface changes and reactions and DFT and ab-initio molecular dynamics simulations from Texas A&M University.

The reviewer pointed out that the work of these institutions is also clearly divided: synergistic multiscale modeling approach at Texas A&M University and Purdue University, SEI formation on amorphous Si surfaces at University of California at Berkeley, the effect of current collector coatings on dendrite formation at University of California at Berkeley, and the passivation role of SEI at PNNL., The reviewer asserted that these collaborators are well coordinated, which is very important to successfully complete this project.

Reviewer 2:

Professor Balbuena, a computational scientist, leads the team. Other members include Professor Seminario, who contributes classical MD simulations, and Professor Mukherjee, who provides mesoscopic modeling. Other collaborators are researchers from UCB (vibrational spectroscopy characterization to characterize SEI formation at the surface of Si anodes), researchers from PNNL (experimental characterization of electrolyte reduction over Li-metal surfaces), and researchers from the University of Illinois at Chicago (experimental microscopy characterization). Overall, the reviewer found that this is a strong team with complementary expertise covering all relevant areas, including both computational and experimental research. The team is extremely productive with both individual PI (or co-PI) and collaborative publications. The total number of the reported published papers is 11, which is very high.

Reviewer 3:

The reviewer found the team to be well organized; and the work done by the team member is complementary to each other.

Reviewer 4:

According to the reviewer, many researchers with different skills contributed to this effort.

Reviewer 5:

The reviewer was glad that this team is working with PNNL to confirm its theoretical predictions with experimental data.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that the future work largely focuses on understanding the effect of electrolyte composition on Li-dendrite formation, Si cracking, and SEI formation. The team will explore Li plating in the presence of K^+ and Na^+ ions as well as the effect of operating conditions (temperature and current rate).

Reviewer 2:
The reviewer said that the team will focus on developing the strategies for controlling the deposition effect on Li-metal and for enhancing the practical utilization of Si anodes.

Reviewer 3:
The reviewer pronounced the work to be very good and noted that relevant future work is planned.

Reviewer 4:
In this project, the reviewer pointed out that further plans have been provided to characterize Li^+ electrodeposition in the presence of other ions (Na^+, K^+) and study the effects of operating conditions (temperature and C-rate on dendrite formation). Macroscopic effects during cycling of Si and Li anodes will be looked at along with identifying electrolyte or electrode additives that may help mitigate the just-discovered chemical effects in Li-metal anodes. Other work involves identifying electrolyte additives or other strategies for Si anodes and developing alternative charging strategies for Li-metal anodes. These plans correspond to the accomplishments and projects goals, but the reviewer found these plans not to be specific enough. The reviewer asked for more details along with considering possible problems and solutions to demonstrate their feasibility.

Reviewer 5:
The reviewer was not sure why the team is planning on investigating Na^+ or K^+. The reviewer liked the idea of determining the effect of C-rate and why dendrites form before mass transfer limits are reached. The reviewer expressed doubt about what a macroscopic effect is with regard to plating. The reviewer appreciated the idea that now that we understand Li-dendrite formation, we need to do something to prevent it. The reviewer did not think that charging strategies are the answer, but who knows.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that this project focuses on evaluating and characterizing interfacial phenomena in lithiated Si and Li-metal anodes; the project also develops strategies leading to controlled reactivity at electrode/electrolyte interfaces using advanced modeling techniques based on first principles, which is crucial for controlling ICL and improving lifetimes. Therefore, the reviewer said that the research approaches in this project are consistent with DOE objectives.

Reviewer 2:
The reviewer affirmed that, if successful, the calculation and simulation will provide insight into the stability of the anode/electrolyte interface.

Reviewer 3:
The reviewer commented that understanding of the SEI formation and mechanical stability of SEI on Si anodes and SEI formation, as well as Li-dendrite growth on Li anodes, which are the focus of this project, are crucial to enable high-energy density Li-ion or Li-sulfur batteries with minimized ICL and maximized lifetimes. Thus,

the reviewer opined that this research is highly relevant to the DOE target of developing next-generation batteries for EV applications.

Reviewer 4:
The reviewer found the work to be very relevant to DOE objective of getting to higher energy densities.

Reviewer 5:
Working on Li-metal anodes is highly relevant, according to the reviewer

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer was enthusiastic about the fantastic progress the PI was making with the present resources.

Reviewer 2:
The reviewer asserted that the resources and equipment are sufficient to implement the project.

Reviewer 3:
The resources available for the team are adequate, according to the reviewer.

Reviewer 4:
The reviewer had no issues with resources.

Reviewer 5:
The reviewer remarked that the group and cooperative institutions in this project are proficient in theoretical calculation and many high-level research papers have been published. In consideration of the research cost, the expenditure in this project is abundant theoretically. Therefore, the group possesses sufficient resources for equipment and researchers to finish the objectives. However, the reviewer pointed out that nearly two-thirds of the time has passed but only 40% of the project has been finished. Therefore, the reviewer urged that the progress should be accelerated.

Presentation Number: bat330
Presentation Title: Electrochemically Responsive, Self-Formed, Lithium-Ion Conductors for High-Performance Lithium-Metal Anodes
Principal Investigator: Donghai Wang (Penn State University)

Presenter

Donghai Wang, Penn State University

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

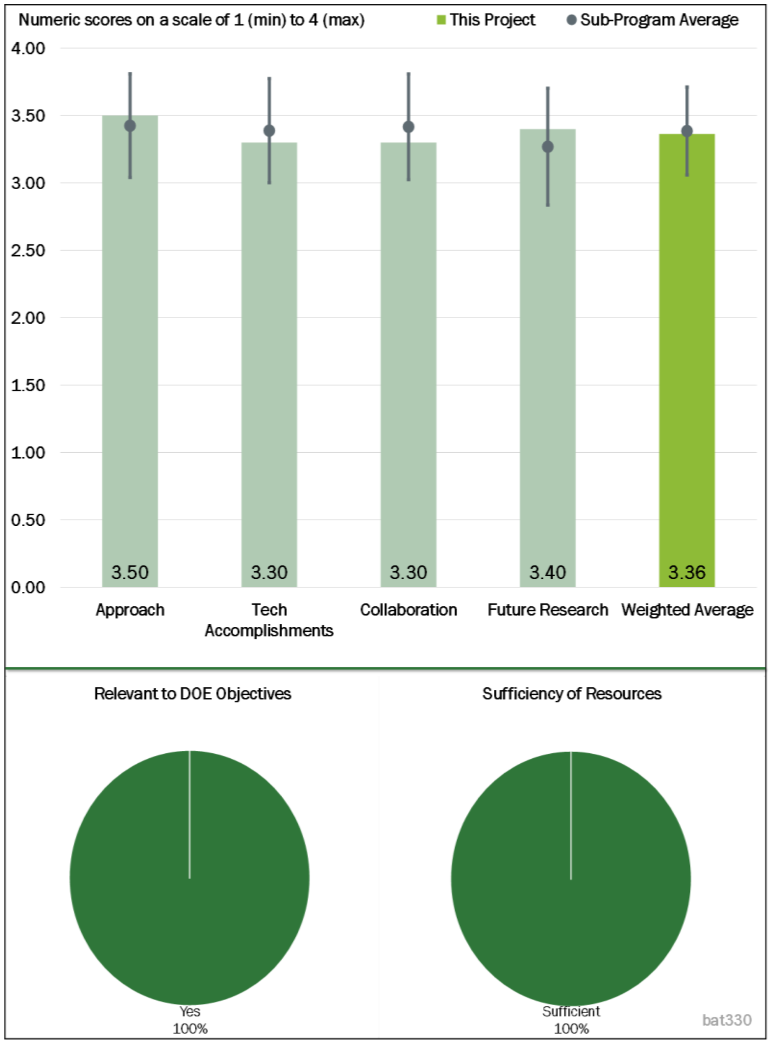

Figure 2-43 - Presentation Number: bat330 Presentation Title: Electrochemically Responsive, Self-Formed, Lithium-Ion Conductors for High-Performance Lithium-Metal Anodes Principal Investigator: Donghai Wang (Penn State University)

Reviewer 1:

The reviewer complimented that the approach based on using a strategy that stabilizes the Li-metal–liquid electrolyte interface by coating the Li-metal surface with multiphase inorganic-organic hybrid ion conductors with tunable multifunctional organic components and controlled inorganic components is quite novel and is well planned. The approach using the different phases seeks to use a SEI with properties for conduction as well as good Li-metal deposition.

Reviewer 2:

The approach is logical and well designed to address one of the major issues confronting the development of a Li-S battery—polysulfide shuttling and an unstable Li/electrolyte interface. To address these issues, the team has a comprehensive plan to develop a self-formed Li-ion conductor as a protective layer for Li-metal anodes. This will in theory enable Li-metal anodes to cycle with a high efficiency. The reviewer found that this a good idea and the PI has laid out a well-designed plan and a realistic time schedule.

Reviewer 3:

The reviewer observed a good concept and approach to try and design multiphase inorganic-organic hybrid ion conductors with tunable multifunctional organic components and controlled inorganic components for Li-metal anodes.

Reviewer 4:

The reviewer commented that many researchers have suggested some type of hybrid approach where a combination of tough inorganic material and soft, polymer forming material are combined to stop dendrites. The project team makes an attempt at this approach.

Reviewer 5:

The reviewer noted that in this project, the team explored new organic Li-and-sulfur-containing additives to form Li-conducting SEI on the surface of a metallic Li anode to enable robust protection and lead to the Li-S batteries with high energy density. The team aim to reaching a goal of Li dendrite-free cycling and CE of greater than 99.7%.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that excellent progress has been achieved this past year. The team was able to demonstrate that organo-Li_xS_y Li protection layers can effectively suppress dendrite growth and significantly improve the cycling efficiency. The team also investigated new cathodes that enable high-sulfur mass loading and a low electrolyte/sulfur ratio.

Reviewer 2:

The reviewer said that improvement in cycling stability is quite good although the CE is still stuck near 99%, which means a full cell cycle life of only 220 cycles if we start with triple the Li excess. The reviewer commented that a much higher CE is clearly needed, which is a real challenge with Li-metal anodes. The reviewer pointed out that these coatings do help CE and impedance rise, which is good.

Reviewer 3:

The reviewer pointed out that the Li in the cell with the second-generation electrolyte appears smoother than with the first-generation electrolyte, and that the XPS shows C-fluoride compounds. The data appear to suggest that there are more organo-sulfides present in the SEI with the second-generation electrolyte and less C-fluoride compounds. The reviewer said the modulus of the SEI appears to decrease with the second-generation, but the reviewer was unable to tell if this is a good or bad thing. The reviewer remarked that the project team obtained more cycles with the new electrolyte and show higher cycling efficiency based on plating and stripping on copper, but all three are around, 99% which is too low for a practical cell. The reviewer said that there is no increase in impedance when switching to the second-generation electrolyte. The reviewer did not understand what the project team is measuring when removing all of the Li from the copper and then performing electrochemical impedance spectroscopy (EIS). The retained capacity is better in a full cell with sulfur as the cathode but no explanation as to why. The reviewer said that the project team does not indicate how much excess Li is used in the cell for full cycling.

Reviewer 4:

The reviewer acknowledged that while significant progress has been made on the coating, the reported CE is not good enough. The PI has not yet shown that that it can be compatible with Li-S system required conditions including mass loading and E/S ratio.

Reviewer 5:

The reviewer commented that the second-generation organo-Li_xS_y additive molecules to be used in electrolytes for metallic Li protection were developed. In comparison to the first-generation linear molecules, the second-generation molecules are cyclic. The reviewer said that the addition of the second-generation additives into the electrolyte showed improved Li anode morphology after 100 cycles, and that Li dendrite growth is partially suppressed. The reviewer remarked that the project team demonstrated a CE of ~99.1% at a current density of 2 mA/cm^2 and capacity of 1 mAh/cm^2, bringing the team closer to its target of 99.7% CE.

The reviewer desired a better explanation about differences between the sulfur-and-Li-containing SEI layer on the surface of the Li anode and reduction of polysulfides dissolved in the electrolyte and related to the shuttle effect. The reviewer asked does Li_2S and Li_2S_2 form in the course of the reduction of the sulfur-and-Li-containing developed organic additives, and how the formed SEI interacts with the polysulfides dissolved in the electrolyte. Additionally, the reviewer desired more results and a better understanding of the effect of the formed Li-and-sulfur-containing SEI on the metallic Li surface. The reviewer pointed out that the team plans to investigate it in the future.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said that the PI has good collaborations for theory and Li-S batteries.

Reviewer 2:
The reviewer was glad to see the team is collaborating with PNNL on making full cells and not trying to figure this out on their own.

Reviewer 3:
The reviewer noted that Prof. Wang at Pennsylvania State University (PSU) leads the project. The collaborators include Prof. Kim (atomic force microscopy characterization) and Prof. Chen (modeling of Li dendrite growth) at PSU and Dr. Liu (fabrication of Li-S batteries) at PNNL. The team is highly productive with five articles, including collaborative articles, published in 2017-2018.

Reviewer 4:
The reviewer commented good collaboration with PSU colleagues as well as with PNNL.

Reviewer 5:
The reviewer observed reasonable collaborations at this stage of the project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that future work is to continue similar development, and that results on Li-metal/sulfur cells are quite promising.

Reviewer 2:
The reviewer remarked that the team is proposing work that is both logical and necessary to move forward. The reviewer said that a new, hybrid organo-Li_xS_y/organo-Li_xPyS_z composite will be developed.

Reviewer 3:
The reviewer detailed that the future work will explore properties of the Li-and-sulfur-containing SEI formed on the surface of a Li anode to suppress growth of Li dendrites in the course of Li-S battery cycling. The team will develop new electrolyte additives with the goal to reach the target CE of 99.2%. Further, the team will develop an inorganic/organic composite protection layer utilizing best-performing organic molecules to reach the CE of 99.7%.

Reviewer 4:
The reviewer pointed that out that future plans are to optimize everything. The reviewer said that there is no indication in these slides how the team plans to optimize the chemistry other than through trial and error, nor is there any reason to believe that through trial and error with the present chemistry the team will achieve much better CE.

Reviewer 5:
The reviewer remarked that the PIs have a reasonable plan to increase the performance of their coating, but little detail was given about how this to be achieved other than using a second-generation coating.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer pointed out that Li anode protection is a high priority for the DOE objectives because of a need to find higher energy density anodes.

Reviewer 2:
The reviewer said that this project is highly relevant and supports DOE/VTO goals. It aims to develop a new Li-ion conductor that will enable high-performance Li-metal anodes. Li-metal anodes can lead to a 50% increase in the energy density of conventional Li-ion batteries with Li-metal oxide cathodes.

Reviewer 3:
The reviewer said that it is highly relevant to work on stabilizing the Li-metal interface.

Reviewer 4:
The reviewer said that developing protective layers for Li-metal does support DOE’s overall objective of improving energy density because it allows going from Gr to Li, which has ten times the capacity for Li per gram of material.

Reviewer 5:
The reviewer said that protection of a metallic Li anode through the formation of a Li-conducting SEI layer with specific chemical composition enabled by the developed Li-and-sulfur-containing new organic molecule electrolyte additives can enable Li-S batteries with high energy density, which is one of the DOE’s targets for the next-generation EV applications.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that resources are sufficient.

Reviewer 2:
The reviewer said that the team has sufficient resources for successful completion of the mission in a timely manner.

Reviewer 3:
The reviewer found that for this trial and error approach, this is enough resources.

Reviewer 4:
The reviewer said that the resources available for the team are adequate.

Reviewer 5:
The reviewer observed good resources.

Presentation Number: bat332
Presentation Title: High Electrode Loading Electric Vehicle Cell
Principal Investigator: Mohamed Taggougui (24M Technologies)

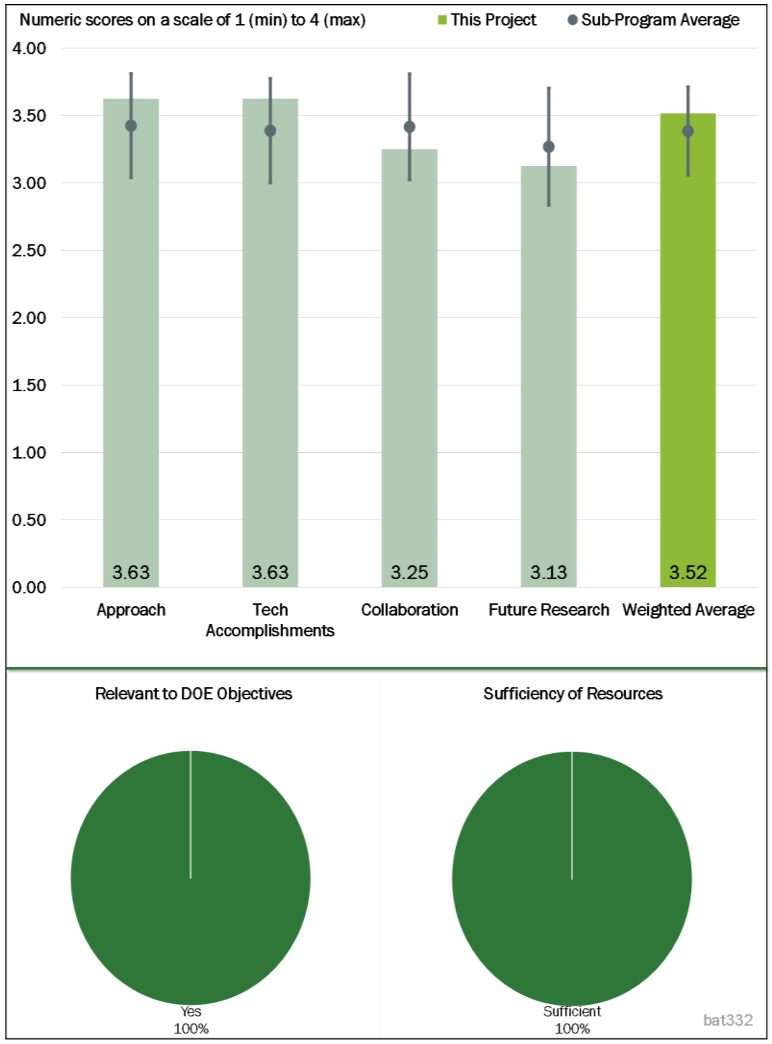

Figure 2-44 - Presentation Number: bat332 Presentation Title: High Electrode Loading Electric Vehicle Cell Principal Investigator: Mohamed Taggougui (24M Technologies)

Presenter

Mohamed Taggougui, 24M Technologies

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented a revolutionary improvement in how to make electrodes and cells.

Reviewer 2:

The reviewer observed a very good understanding of the practical limitations on electrode design and production at high volume. The reviewer had some concern about market adoption of single side coated electrodes into high-volume cell assembly and ability to roll-to-roll (R2R) produce and process the electrodes. The reviewer said that pot life and fill/formation protocols are acceptable for transfer to industry.

Reviewer 3:

The reviewer pointed out that regarding ruggedness, the project team got the European Council for Automotive R&D (EUCAR) classification of EUCAR 1, and the pressure test shows no leaking, fire, explosion, or exothermical reaction. However, other issues, such as cost and performance, are not mentioned. The reviewer recommended that the project needs to address abuse, tolerance, and reliability barriers collectively.

Reviewer 4:

The reviewer said very interesting concept with a thick electrode, and the project needs to perform extensive rate and cycling studies, and a cost evaluation of the pre-lithiation step.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said tens of thousands of cells, and commented that because the team has substantially reduced the amount of non-active material in the cells, an enormous cost advantage is possible

Reviewer 2:

The reviewer said that the team has made clear strides in cell development and testing, and the team needs to evaluate rate and elevated temperature stability.

Reviewer 3:

The reviewer said that the team has done a good job addressing issues with viscosity limits of high solid loading electrodes. The reviewer pointed out there may be an issue with vehicle adoption, but other significant low-cost energy storage markets can be pursued. The reviewer noted that abuse tolerance benefits may compensate for Wh/L Wh/$ trades for lower solid loading. The reviewer pointed out that the references to pre-lithiation and Si volume expansion are tantalizing but not substantiated.

Reviewer 4:

The reviewer pointed out that the entire program is progressing objectively. However, improvement of the energy density is needed, beyond the 64.5% of program goal; though the team completed the reduction of use of inactive material, as well the abuse tolerant battery systems and the mass production.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said good collaboration and coordination with partners.

Reviewer 2:

The reviewer noted that partnerships in all parts of the world have been set up. The team has backing from a large energy company

Reviewer 3:

The reviewer said collaboration looks to be only with 24M, and that the team should work with Sandia National Laboratories on testing.

Reviewer 4:

The reviewer said neutral score, and elaborated no funded collaborators on program, but no obvious capability gaps either

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that the spending pace seems to be lagging a bit, but very good identification and prioritization of the gaps in commercialization.

Reviewer 2:

The reviewer said that future work well-coordinated with the design and system working. The next step is the coating, which is needed for one of the team’s goals to eliminate barriers.

Reviewer 3:

The reviewer commented that the company wants to supply the automotive industry. There are some possible drawbacks. The reviewer pointed out that auto suppliers traditionally are not very profitable. The reviewer said that the project's power capability may not be good enough for vehicles, but they are in a great position for grid storage.

Reviewer 4:

The reviewer described proposed future research as overly broad and vague, and indicated the need to identify challenges or else this project should be deemed a success.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that the project definitely meets DOE objectives with reducing cost of EV batteries to spur vehicle electrification and domestic production, and that the project should also be relevant to the grid. The reviewer said that this is an exemplary DOE program in terms of technical risk/reward and solid understanding of scale up.

Reviewer 2:

The reviewer said that the project supports DOE objectives as it plans to increase the energy density and ruggedness of a battery, which is highly needed for EVs.

Reviewer 3:

The reviewer pointed out a big cost reduction for grid storage.

Reviewer 4:

In this reviewer's opinion, reducing copper will be a significant improvement and help drive down the cost of the cells. The reviewer recommended that future work should include economic analysis of the cell and components.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that resources are sufficient.

Reviewer 2:

The reviewer said that resources are sufficient, considering that the team needs to increase the energy density by 35.5% to reach the program goal.

Reviewer 3:

The reviewer said that 24M is making timely progress against milestones.

Reviewer 4:

The reviewer said that resources are okay.

Presentation Number: bat344
Presentation Title: Electrolyte Reactivity and Its Implication for Solid-Electrolyte Interface (SEI) Formation
Principal Investigator: Kristin Persson (Lawrence Berkeley National Laboratory)

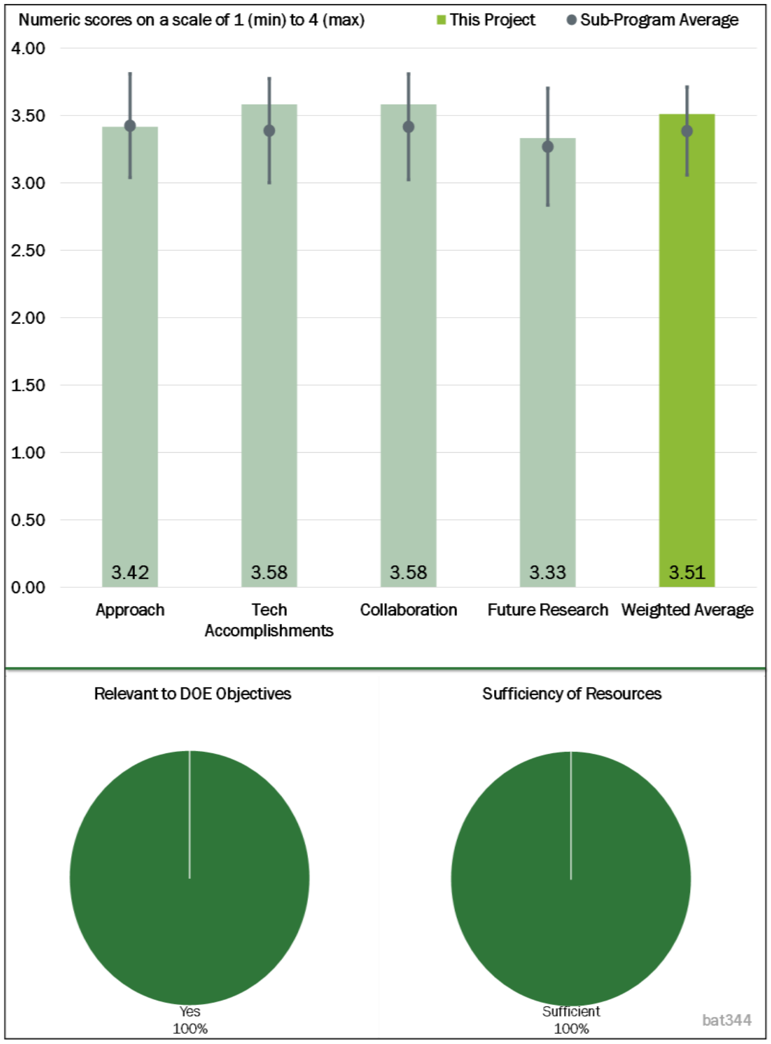

Figure 2-46 - Presentation Number: bat344 Presentation Title: Electrolyte Reactivity and Its Implication for Solid-Electrolyte Interface (SEI) Formation Principal Investigator: Kristin Persson (Lawrence Berkeley National Laboratory)

Presenter
Kristin Persson, Lawrence Berkeley National Laboratory

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer said that this project aims at the interfacial chemistry between Si anode and electrolyte. With extensive cooperation, the project team combines the computational and experimental methods to probe the underlying science of the SEI formation as a function of electrolyte formulation, Si surface composition, and battery cycling. The reviewer said that the achievements in this project are promising to inspire and guide the mechanism study as well as material engineering for an advanced Si anode, which is significant in the development of next-generation and commercially viable Li-ion batteries. The feasibility of this project is good, the scheduling is reasonable, and considerable staged results have been achieved. The reviewer expressed optimism that the project can be well-accomplished on time.

Reviewer 2:
The reviewer commented that this is a well-thought out, well-planned team project to characterize the surface reactions that take place on Si (and related materials), and the approaches are outstanding. However, that is not the only key barrier that needs to be addressed—especially the electro-mechanical aspects of the reactions. The reviewer did not see that aspect of the work being an integral part of the studies.

Reviewer 3:
The reviewer said that the researcher addressed the strengths and weaknesses of the technical barriers clearly. The reviewer said that the project is using molecular dynamics calculations to understand the problem, and noted clearly defined research carried out a feasible way.

Reviewer 4:

The reviewer said that this project was one of the multiple projects aiming for a better understanding of interaction between electrolyte and Si-based anodes. This work provides the first step of understanding through thermodynamic calculations and validations.

Reviewer 5:

The reviewer remarked very nice work; important and informative. The reviewer noted that the project is well-connected to the other DOE Si projects. The reviewer said that the project could be improved by better (and direct, instead of just relevant literature) experimental support to validate the conclusions.

Reviewer 6:

The reviewer said that the first-principles and simulation-based work is well-designed and provides excellent support of, direction for, and validation of much of the more experimental activity of the other partners in the Silicon Electrolyte Interface Stabilization (SIESta) team.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted excellent technical progress with very impressive results has been achieved in this project. It is gratifying to see how much can be modeled today using the latest computational techniques and resources and more importantly how well these data align with experimental values. The reviewer said that calculating the percentages of solvent-separated or contact ion-pairs as a function of additives, their impact on reduction potential at different surfaces, etc., provide important theoretical insights to understanding SEI characteristics of Si-based anodes.

Reviewer 2:

The reviewer said that the combination of theoretical, experimental, and simulation strengthens the progress of the overall project. The reviewer said that relevant correlations have been established against performance indicators.

Reviewer 3:

The reviewer said that the project is on-track.

Reviewer 4:

The reviewer said that it is very nice to see the fundamental studies of electrolyte species in bulk electrolyte, a Si anode, and their interface with and without additives. The project team validated simulation results with various experiments confirming the accuracy of calculations. The reviewer said that it would be nice to expand this type of research with more practical electrolyte combinations.

Reviewer 5:

The reviewer pointed out that it is claimed that higher temperature favors the formation of contact ion pairs in both bulk and at the interface. However, the related information is missing. The reviewer explained that the extent of such impact as well as the underlying mechanism is worthy of investigation because the temperature-induced performance fluctuation is very important and challenging in battery development.

As demonstrated, this reviewer indicated that Li diffusion in the native surface SiO_2 is a kinetic bottleneck for lithiation of Si anode. The reviewer asked what the possible solution is to such a kinetic barrier. Additionally, the reviewer inquired about the SEI formation reactions when the SiO_2 shell was artificially stripped (or on pure Si surface).

Reviewer 6:

The reviewer noted useful findings, in particular regarding the voltage-based stability, and the phase and voltage profile phenomena.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer observed a superb collaboration team.

Reviewer 2:

The reviewer commented that including different DOE national laboratories' expertise and researchers from academia is very thoughtful and enables the author to perform the mission very well.

Reviewer 3:

The reviewer said that through collaboration with various national laboratories and universities, each calculation was verified with empirical data.

Reviewer 4:

The reviewer remarked that project partners participated actively and are well-coordinated.

Reviewer 5:

The reviewer commented that collaboration on the project within the national laboratory system partners appears to be and should be able to be well-coordinated. The reviewer said that collaboration with university partners appears to be well-coordinated as well. The reviewer was concerned about an absence of any partnership with an industrial electrolyte supplier and this could limit maximum relevance.

Reviewer 6:

The reviewer remarked that coordination was well-connected within DOE, but please seek experimental support to validate the conclusions.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer pointed out that ESI is a known phenomenon and the author has identified different approaches to address this in future research proposal.

Reviewer 2:

The reviewer found that the future direction is clear and relevant.

Reviewer 3:

The reviewer said that the proposed future research is logical, including milestones and risk management.

Reviewer 4:

The proposed work exploring interfacial speciation, their characterization, impact of different electrolytes on SEI, etc. all look good. The reviewer recommended including the mechanical aspects to this work. The reviewer asked if the swelling characteristics can be estimated as a function of electrolytes, and alloy compositions.

Reviewer 5:
The reviewer commented that the plan to focus on early SEI components and subsequent disposition is excellent. The reviewer suggested that additional focus areas for further consideration could include related impact of cathode and/or binder decomposition products in electrolyte.

Reviewer 6:
The reviewer said that the team has a solid plan for the next step. However, it would be nicer to look at broader research results with more practical electrolyte compositions or SiO_x, which is more favorable to the Li-ion battery industries.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer agreed yes, the project supports DOE's overall objectives in advancing the path towards energy density increase via Si-anode implementation.

Reviewer 2:
The reviewer said that cost, performance, and safety are the DOE objectives with respect to batteries and the author clearly identified these at the onset of the research.

Reviewer 3:
The reviewer commented that the Si-based anode is the choice for delivery of an advanced Li-ion battery with higher energy density and low cost, which has a great potential to meet DOE's goals for EVs. The fundamental studies through this project can give a better understanding of the electrochemistry of a Si-based anode and electrolyte providing clues on how to tackle the major life issues associated with Si-based anodes.

Reviewer 4:
The reviewer said that DOE's goals to understand and improve Si negative materials are important and relevant to industry. The fundamental modeling effort is an important and necessary part of this work.

Reviewer 5:
The reviewer commented that this project supports the overall DOE objectives, the development of PHEVs and EV batteries that meet or exceed the DOE and USABC goals.

Reviewer 6:
The reviewer found that better insights into the SEI characteristics of the Si anode clearly have relevance to the overall DOE objectives of developing better battery technologies. However, as is now well-accepted, mere understanding and improving the SEI characteristics alone will not allow the Si-based anode to be developed into a practically useful anode. The swelling features need to be understood and contained and that did not receive that much focus in the overall project (not this specific project only).

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer found that the research team has sufficient funding, human resources, and equipment to complete the project.

Reviewer 2:
The reviewer commented that resources appear in-line with work plan.

Reviewer 3:

The reviewer said that the PI and the project team have deep knowledge on the molecular dynamics. LBNL has electrochemistry teams who can support this project within LBNL but through a well set-up collaboration with various national laboratories and universities, technical support, and direction can be provided for delivery of meaningful results.

Reviewer 4:

The reviewer said that relative to other projects, the resources seem significant, but appropriate given the scope of activity and the number of partners.

Reviewer 5:

The reviewer said that with involvement from academia and different DOE national laboratories, resources are plenty for this research.

Reviewer 6:

The reviewer referenced prior comments. The reviewer was a bit unclear whether the $3.9 million was used only for this project (which sounds very, very high) or among the consortium members.

Presentation Number: bat345
Presentation Title: Chemical Reactivity of Silicon at the Surface
Principal Investigator: Gabe Veith (Oak Ridge National Laboratory)

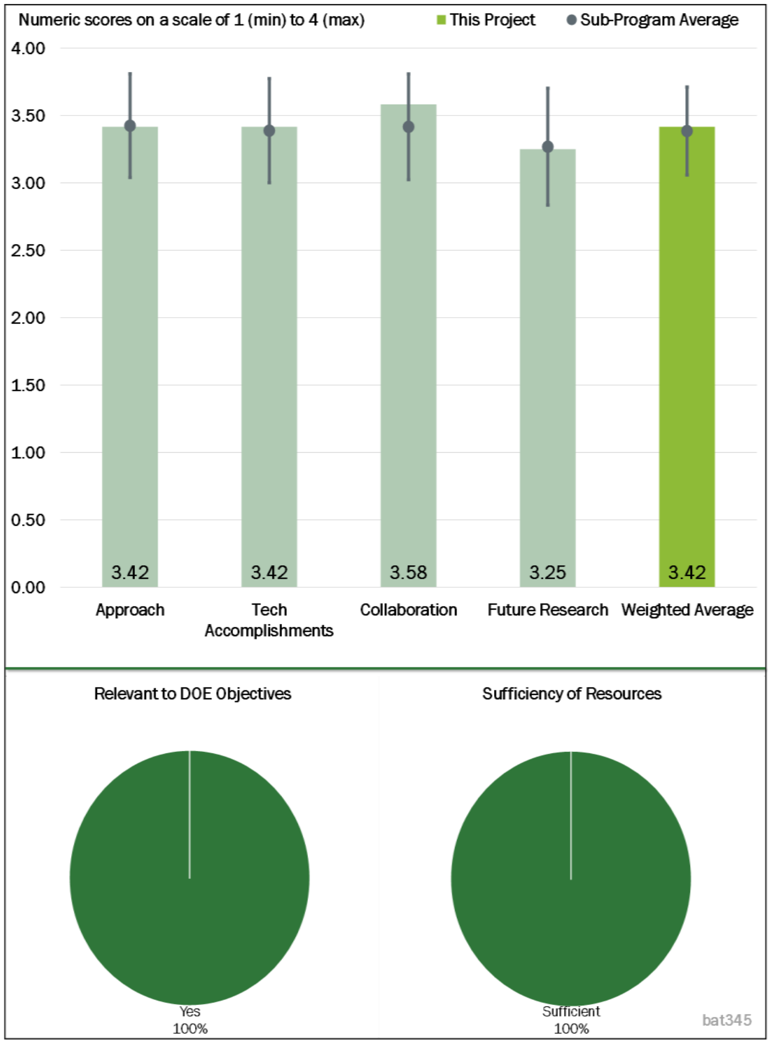

Figure 2-47 - Presentation Number: bat345 Presentation Title: Chemical Reactivity of Silicon at the Surface Principal Investigator: Gabe Veith (Oak Ridge National Laboratory)

Presenter

Gabe Veith, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted a very effective approach built on extensive collaboration and standardization of materials and architectures. The reviewer commented very well-designed work progress.

Reviewer 2:

It is a very focused and well-planned approach entailing several common as well as novel techniques such as tip-enhanced Raman spectroscopy (TERS) and neutron reflectometry to characterize chemical reactions that take place on Si and analogous material surfaces as well as other electrode components when in contact with electrolytes as a function of time. However, as noted in other projects of this consortium, and in this reviewer's opinion, including a work that would also look at the chemical reactions on the Si materials once they have undergone swelling/pulverization would also be very instructive.

Reviewer 3:

The approach seems well-planned and well-executed so far with very useful resulting findings coming from practical and feasible experimental observations.

Reviewer 4:

The reviewer said that the approach is good and the project contributes to achieve the overall goals of the SEI stabilization (SEISta) program. This project also prepares standard Si thin film samples as one of the model systems distributing among various projects. The reviewer said that the FTIR technique was heavily used in the studies. The reviewer pointed out that while it is effective with certain gases, not all gases produced during the reactions may be detected. The reviewer recommended bringing in other analytical techniques such as mass spectrometry in gaining better understanding of the gassing behavior of Si-anode materials.

Reviewer 5:

The reviewer remarked very interesting study. The time to reaction onset needs to be further investigated to understand the mechanism. The reviewer thought that the experimental setup was very well done, with built in checks for contamination/leaks.

Reviewer 6:

The reviewer remarked that the research objective is not often handled by other organizations and interesting. However, the approaches to resolve the possible issues are not clearly addressed at the beginning of the talk. The reviewer said that it was clearer through detailed review of the presentation.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said extensive studies with well-defined Si material surfaces with temporal monitoring and characterization of the products as a function of electrolytes have led to a rich set of results that provide very useful insights into the nature of the gaseous products and the associated surface chemistries.

Reviewer 2:

The reviewer said that the researcher's effort to understand the changes in material behavior is very effective to achieve the overall project success. The researcher attempted to capture as much quantitative information as possible to understand the surface characteristics.

Reviewer 3:

The reviewer found that the project has made significant progress. The reviewer wondered why the gassing studies were only limited to conditions under chemical reactions. It seems rather important to perform these studies under both chemical and electrochemical conditions. One cannot really separate chemical and electrochemical processes or gaseous versus non-gaseous products.

The reviewer recommended better characterization of the Si surface properties, especially in the dissolution studies. The nature of the surfaces oxide has large influence on the dissolution behavior. On the same front, better control of the liquid electrolyte quality is important in order to get meaningful results. The reviewer would like to understand how electrolyte quality was ensured for the studies. The reviewer would also like to see more linking between insights learned from these specific studies and how they would be used to improve performance and stability of the real-world Si-anode materials. The reviewer was not clear how all these understanding will ultimately be used to advance Si-anode materials.

Reviewer 4:

The reviewer pointed out that electrolyte reactivity with Si materials is a complex but critical to understand topic. Even though there is still a very long way to go, this project showed progress towards a better understanding.

Reviewer 5:

The reviewer said that it was very practical to try running experiments with various Si-based materials and electrolyte compositions to back up the major findings. However, according to the reviewer it would be better to include more details on possible mechanisms of the chemical reactions presented.

Reviewer 6:

The reviewer commented that although significant results were obtained with most of the areas studied and techniques applied, the gas evolution observations, while not trivial to carry out, seem in particular to have provided key and tangible findings. The reviewer found that of all of the methods applied or developed, the TERS output so far seems to be the least useful in terms of tangible advancement in understanding.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer found that the project had excellent collaboration among the teams with complementary strengths and roles.

Reviewer 2:
The reviewer said that a broad-based collaboration among DOE national laboratories and academic institution researchers strengthens the analysis.

Reviewer 3:
The reviewer said that some of the key findings were obtained through various analyses techniques from collaborators. The authors nicely referred to the projects that specifically focus on the analytical techniques.

Reviewer 4:
The reviewer said that the project was well coordinated with other DOE Si projects.

Reviewer 5:
The reviewer said that collaboration on the project within the national laboratory partners appears to be and should be able to be well-coordinated. The reviewer found that collaboration with university partners appears to be well-coordinated as well. The reviewer pointed out that the absence of any partnership with industrial electrolyte supplier may be of some concern and could limit maximum relevance.

Reviewer 6:
The reviewer said that collaboration across the team is excellent. However, the reviewer noticed that there appears to be significant overlap among the individual Si projects within the SEISta program. BAT345, 346, and 347 are especially closely related and perhaps better combined into one larger project so that studies are better coordinated to minimize duplication.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the proposed future research clearly identifies the technology gap and risks in the project. The researcher attempted several known risk mitigation strategies.

Reviewer 2:
The reviewer said that the future direction is clear and relevant.

Reviewer 3:
The reviewer noted that in initial phases, investigation of chemical activity of Si anode surface was a focus. Prior to varying experimental design parameter change for the next steps, the reviewer recommended scrutinizing mechanisms of gas and surface film formations for better understanding of surface chemistries and plan for the future research.

Reviewer 4:
The reviewer said that the proposed future work entailing the effect of material composition and surface looks good. However, that work more than likely will not be enough to design a Si anode that will be functionally robust enough for long-term cycling. The reviewer recommended that this work needs to be complemented by studies that addresses the large swelling of the Si anode.

Reviewer 5:

The reviewer said that overall, the proposed future work is logical. Considering gassing impacts the entire cell and cross talk is known to exist, the reviewer recommended that full cell studies are performed in the future. The reviewer recommended that in order to stay relevant to the real working Si anode materials, other model systems should be created and examined. One recommendation is to build model systems based on the knowledge currently existing in the literature and in the industry, particularly in terms of surface properties. The reviewer pointed out that the industry has had great success in developing Si anode materials over the years and there is a vast amount of knowledge on what works well and what does not. In that sense, bringing in an industry partner would greatly strengthen the effort. In addition to the native Si surface, SEI on Si is known to be affected by electrolytes and additives used. The reviewer suggested incorporating more electrolyte work to speed up the learnings.

Reviewer 6:

The reviewer said that the proposed future research seems excellent and should result in even greater relevance and findings for the overall project. The intent and timing to introduce greater complexity (binder, carbon black, etc.) of factors into observations is excellent. The reviewer said that including trace quantities of cathode decomposition products into the electrolyte could be a further additional step towards results of interest.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that understanding surface reactivity is a key requirement for developing a stable Si anode and hence this project does meet the DOE overall objectives of developing a high-energy battery to facilitate EV adoption.

Reviewer 2:

The reviewer commented that a newer anode material to enhance the current battery technology is one of the key DOE objectives and this research perfectly fits the objectives.

Reviewer 3:

The reviewer remarked that the outcome of this research can improve understanding of initial stages of SEI formation on Si anode providing direction for experimental design change and material selections for improvement of life of advanced battery technologies.

Reviewer 4:

The reviewer said that improving the performance of Si anode material is critical in achieving the high energy density needed in next-generation Li batteries. The project supports the overall DOE objectives and it is very relevant.

Reviewer 5:

The reviewer agreed that yes, the project supports overall DOE objectives in advancing the path towards energy density increase via Si anode implementation.

Reviewer 6:

The reviewer cautioned please be careful to maintain relevance especially given the dwell time to reaction. The reviewer said that industrial users will not wait hours before forming the cell.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the involvement of different DOE national laboratory researchers and well-established academic institution resources are very helpful and sufficient to achieve the milestones and deliverables on time.

Reviewer 2:

The reviewer remarked that resources are in-line with the work plan.

Reviewer 3:

The reviewer said that a breakdown of funds to individual national laboratories would have been helpful in answering this question. But judging from the work scope, it appeared to the reviewer that the funds are sufficient.

Reviewer 4:

The reviewer said that the project teamed up with other research organizations for extensive surface analyses using various techniques. The reviewer said that an additional team for modeling possible mechanisms of film and gas formations would be beneficial.

Reviewer 5:

The reviewer was unclear how much funding this project receives so it was difficult for the reviewer to judge whether or not enough resources are available. However, the overall SEISta program has sufficient resources.

Reviewer 6:

The reviewer said that relative to other projects, the resources seem significant, but appropriate given the scope of activity and the number of partners.

Presentation Number: bat346
Presentation Title: Spectroelectrochemistry of Silicon Model Electrodes
Principal Investigator: Robert Kostecki (Lawrence Berkeley National Laboratory)

Presenter

Robert Kostecki, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

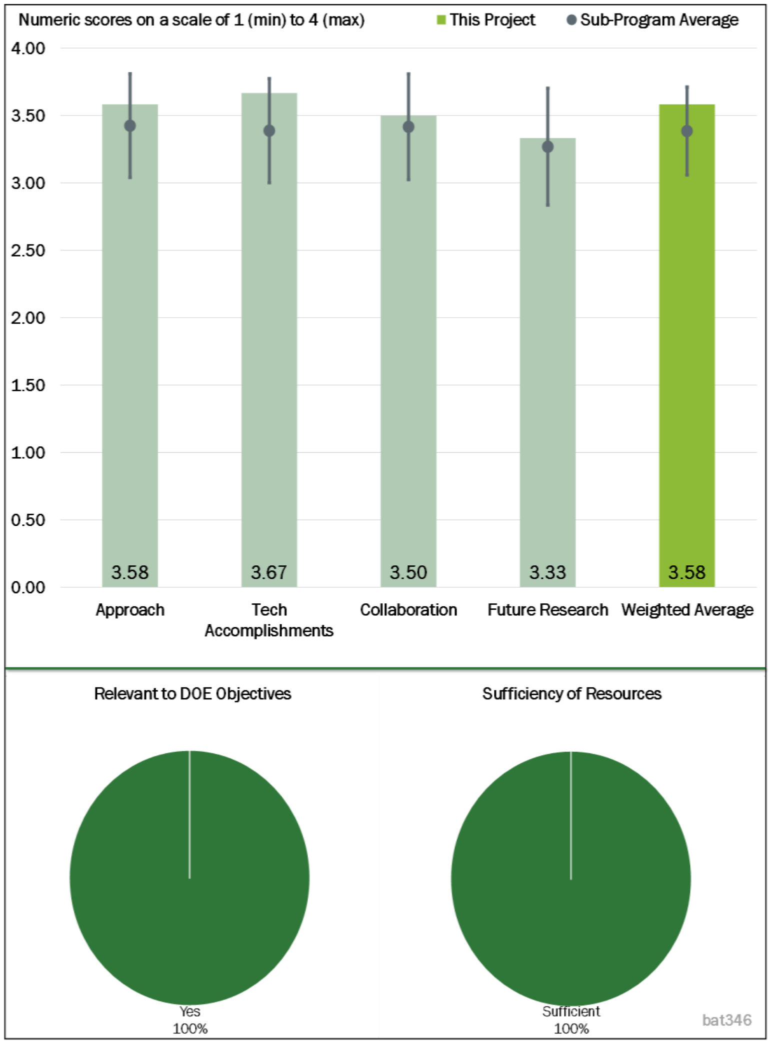

Figure 2-48 - Presentation Number: bat346 Presentation Title: Spectroelectrochemistry of Silicon Model Electrodes Principal Investigator: Robert Kostecki (Lawrence Berkeley National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the researcher’s analysis is sharply focused on barriers and underlying cause. The well-designed project effectively addresses the technical barriers.

Reviewer 2:

The reviewer said that the project has a sharp focus to characterize key components of the SEI layer that forms on Si materials utilizing an array of spectroscopic tools. The approach is well-planned and comprehensive.

Reviewer 3:

The reviewer remarked that the project nicely balances its own work and information from the literature for possible explanations of SEI layer appearance/disappearance during cycling, and mechanisms of each constituent of the SEI layer on a Si anode.

Reviewer 4:

The reviewer observed a unique and innovative approach. The reviewer said that results are very informative and critical to understand.

Reviewer 5:

The reviewer said that the project work is well-focused with the application of select analytical techniques and dynamic behavior of SEI on model materials with cycling.

Reviewer 6:

The reviewer detailed that this project involves the development a novel Li-ion negative electrode based on Si as the active material. The project so far includes the characterization of SEISta model research samples by

XPS, secondary ion mass spectroscopy (SIMS), IR, and Raman before and after contact with electrolyte, before cycling, and characterizes the nature of the electrolyte decomposition products in SEI. The team is also investigating the growth rate of SEI layer at fixed potential during cycling. The reviewer suggested that the authors also try to correlate SEI layer growth rate to the crack formation and propagation during cycling. The reviewer said that this could be obtained by taking various SEM/TEM images at different cycles.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the project has made significant progress towards its technical goals with high-quality results. Using a variety of tools such as XPS, SIMS, and Raman, the team was able to identify and monitor key SEI components such as LiEDC as a function of lithiation and de-lithiation. The reviewer found that data that unambiguously showed the appearance and reappearance of species such as LiEDC are quite insightful and instructive.

Reviewer 2:

The reviewer said that this work is going a long way toward further understanding (if not yet mitigating) the SEI instability on Si surfaces.

Reviewer 3:

The reviewer said that the researcher performed extensive analysis to understand the lithiation/de-lithiation between different cycles both qualitatively and quantitatively. The reviewer remarked that the researcher made several key observations to establish the relationship between SEI thickness and composition in relation to SOC.

Reviewer 4:

The reviewer commented that the research team showed evidence of SEI layer composition on Li-silicate during charge and discharge using spectro-electrochemistry analytical techniques and offered the insights into dynamic behavior of the pseudo passivation layer during cycling. An outcome of this research will be a good reference for tackling the issue associated with an unstable passivation layer on a Si-anode.

Reviewer 5:

The reviewer said that findings via ATR FTIR in understanding the dynamic behavior of SEI on model materials at varying degrees of lithiation seems of particular value in better understanding the nature of the mechanisms involved as well as in advancing the understanding of the scope of the Si SEI stability issue.

Reviewer 6:

The commented that the FTIR results are presented for the first and second lithiation/de-lithiation. The reviewer asked how the author can make sure that LiEDC re-appears for the upcoming cycles. Secondly, the reviewer asked how the Si particle size affects the SEI layer growth rate. This is because Si lithiation and de-lithiation behavior is highly depended on the particle size.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted great collaboration with ORNL and NREL for the sample electrode and the unique three-electrode cell design for the ex situ FTIR analysis.

Reviewer 2:

The reviewer noted a very well-coordinated collaboration among different DOE national laboratories and academic researchers to establish common ground for the research

Reviewer 3:
The reviewer said that the partners participated and are coordinated.

Reviewer 4:
The reviewer commented that the project is well-connected to other DOE Si projects.

Reviewer 5:
The reviewer said that the project had excellent collaboration across the various teams. The reviewer said that a team member is absent here that addresses the mechanical aspects of overall project.

Reviewer 6:
The reviewer noted collaboration on the project within the national laboratory system partners appears to be and should be able to be well-coordinated. Collaboration with university partners appears to be well-coordinated as well. The reviewer noted that the absence of any partnership with an industrial electrolyte supplier may be of some concern and could limit maximum relevance.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted a well-thought out plan for future research to address challenges and barriers. The reviewer said that researchers identified the key questions to be addressed.

Reviewer 2:
The reviewer observed a solid work plan for the next step for characterizing various high-energy anode material candidates using the similar analytical techniques. The additional work will provide more insight into interfacial properties of the Si-anode using a new in situ FTIR and XAS measurements.

Reviewer 3:
The reviewer said that the proposed future research is logical and includes milestones and risk management.

Reviewer 4:
The reviewer said that the future direction is clear. The reviewer said the project could be further improved by linking the results to electrochemistry (dQ/dV, CE, and performance). In addition, it would be interesting to verify methods by experimenting with controls (such as Gr) that have a known, stable SEI.

Reviewer 5:
The reviewer commented that the intent for investigating modified versions of model electrode materials is excellent. The reviewer was unsure of the relative value of further development of a near-IR approach compared to already clear and valuable findings from ATR FTIR.

Reviewer 6:
The reviewer said that the proposed future research aims to further characterize the SEI components, take inventory of Li, and develop additional analytical tools to characterize interfacial phenomena as a function of cycling will address the project goals. The reviewer, however, did not see much value to digress into alternative anode work entailing tin, germanium, or antimony.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that understanding the SEI stability on Si surfaces is a critical first step to improvement. This work is focused and relevant.

Reviewer 2:
The reviewer said that identifying and characterizing key components of the SEI that forms on the Si, especially during charging and discharging, is an essential requirement to develop a stable Si anode that is in full agreement with DOE overall objectives of higher density batteries.

Reviewer 3:
The reviewer said that overall DOE objectives are met.

Reviewer 4:
The reviewer pointed out that this project involves fundamental research to tackle the barriers associated with development of an advanced Li-ion battery using a high specific energy anode offering a great potential for more efficient packaging, longer driving range, and low cost of electrified vehicles.

Reviewer 5:
The reviewer said that this project supports the overall DOE objectives, specifically the development of PHEV and EV batteries that meet or exceed DOE and USABC goals.

Reviewer 6:
The reviewer agreed yes, the project supports overall DOE objectives in advancing the path towards an energy density increase via Si anode implementation.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
As commented on other projects, the reviewer believed that the funding level is sufficient, although a breakdown for the individual national laboratories was not given.

Reviewer 2:
The reviewer said that the research team has sufficient funding, human resources, and equipment to complete the project.

Reviewer 3:
The reviewer said that resources are in-line with work plan.

Reviewer 4:
The reviewer said that sufficient resources have been allocated for this research. The reviewer recommended that involvement of an industry partner will augment this research from a commercial perspective.

Reviewer 5:
The reviewer remarked that the project team works efficiently based on deep knowledge on formation mechanisms of various key species of SEI layer and experience in analytical techniques. The reviewer said that collaboration with material experts extends the project team’s research capabilities with which the project goal can be met as planned.

Reviewer 6:
The reviewer said that relative to other projects, the resources seem significant, but appropriate given the scope of activity and the number of partners.

Presentation Number: bat347
Presentation Title: Surface Analysis of the Silicon Solid-Electrolyte Interface (SEI)
Principal Investigator: Chunmei Ban (National Renewable Energy Laboratory)

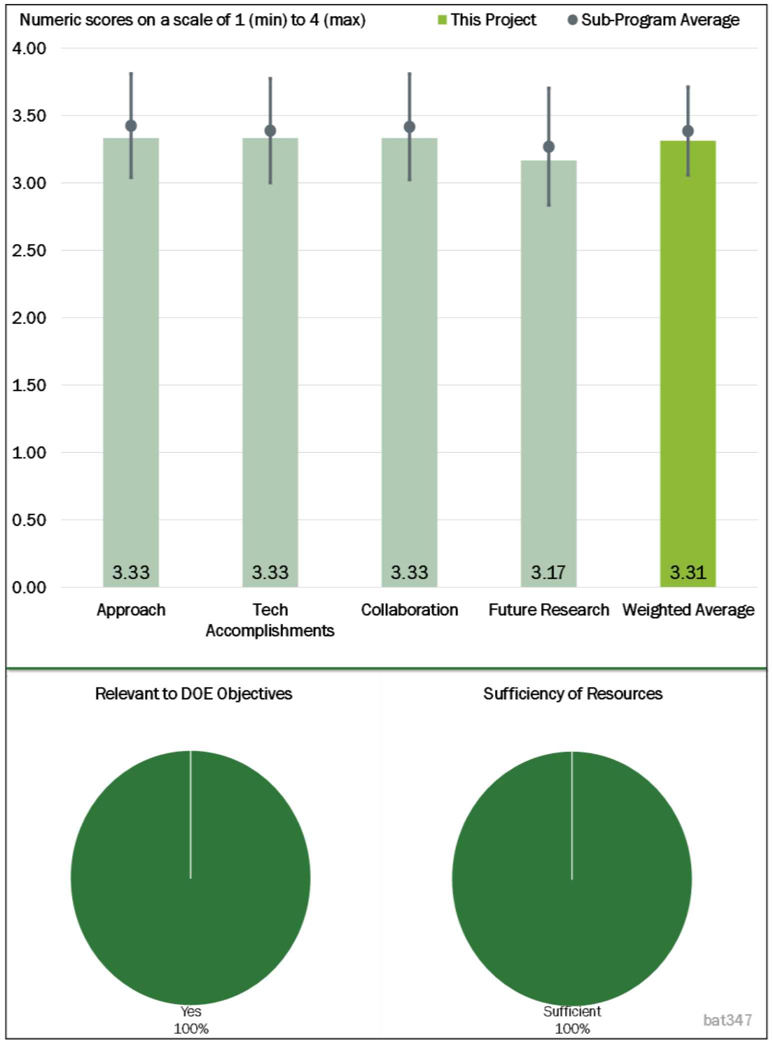

Figure 2-49 - Presentation Number: bat347 Presentation Title: Surface Analysis of the Silicon Solid-Electrolyte Interface (SEI) Principal Investigator: Chunmei Ban (National Renewable Energy Laboratory)

Presenter

Chunmei Ban, National Renewable Energy Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that this project has a good focus on facets of the overall Si interface issue such as thickness, conductivity, and nanostructure of the SEI that complements work carried out by other consortium members. The approach is well-thought out and well-executed.

Reviewer 2:

The reviewer commented that the researcher attempted to address certain barriers in this research. The reviewer found that overall, it is well defined.

Reviewer 3:

The reviewer noted a unique and innovative approach to understand SEI on Si.

Reviewer 4:

The reviewer found that the project appears to be somewhat of a shotgun approach to apply or develop a variety of diagnostic methods towards better understanding of Si SEI composition, structure, and electrolyte effects, and the target is hit with a number of the diagnostic approaches.

Reviewer 5:

The reviewer said that general approaches were employed to identify initial SEI layer formation on a Si anode. However, it would be more meaningful to diagnose the change (i.e., composition, dimension, etc.) associated with aging (both electrochemical cycling and thermally). The reviewer said that it would be helpful to better understand the SEI layer on a Si anode if compared to that on the well-known Gr. The reviewer said that approaches for broader work scopes would be ideal to see the effects of other active electrode layer components on the SEI layer formation.

Reviewer 6:

The reviewer remarked that overall, the project is well planned and it nicely compliments the SEISta program. Using the same model systems across the various projects is an excellent approach to gain comprehensive understanding on fundamental phenomena and processes occurring on Si anode materials. The reviewer, however, would like to see more connection to the "real world" materials, especially those produced by some of the most successful Si anode companies. The reviewer opined out that there is a vast amount of knowledge already accumulated on Si (as to what works and what does not), both in the literature and in the industry, so starting from "ground zero" may not be the fastest route to address some of the technical barriers facing researchers today.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that this project has obtained a number of interesting results that definitely provide valuable insights into the characteristics of the Si SEI. For example, the authors used novel diagnostic tools such as TERS to probe the heterogeneity of the surface down to the nanoscale level, and measured the conductivity of the SEI layer as a function of depth. The reviewer said that these are really state-of-the-art results allowing direct correlation and more importantly direct visualization of nanoscale level particles with electrolyte/surface factors.

Reviewer 2:

The reviewer said that good progress was made with excellent spectroscopy results and quantifiable data at different cycles. The reviewer remarked overall, good progress.

Reviewer 3:

The reviewer noted interesting and informative results, and that the results highlight the extremely complex nature of SEI on Si.

Reviewer 4:

The reviewer said that while not all of the diagnostic method approaches utilized may be of equal value, the scanning spread resistance microscopy (SSRM) method and results seem to indicate a particularly valuable and novel approach towards better understanding of the SEI and the impact of electrolyte composition on SEI resistance and SEI structure.

Reviewer 5:

The reviewer pointed out that this is a challenging topic and the project has made good progress on understating SEI on Si materials. Using SSRM measurements is interesting and potentially useful in understanding the electric properties of the SEI. The reviewer suggested that the PI should consider the porous nature of SEI and how that plays a role in the measurements. It is also not clear what is the depth resolution of the technique.

The reviewer would like to see more linking between insights learned from these specific studies and how they would be used to improve performance and stability of Si anode materials. The reviewer said it is not clear how all these understandings from various studies will ultimately be used to advance Si anode materials as we know today.

Reviewer 6:

The reviewer said that it is very nice to see extensive electrochemical analyses for characterization of SEI layer on a Si anode, but it would be very helpful to see similar analytical results with more electrolyte combinations and electrode components.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said that the project had excellent collaboration across the teams that possess complementary strengths.

Reviewer 2:
The reviewer noted the project established good collaboration to achieve the project goal.

Reviewer 3:
The reviewer said that the project is well coordinated with other Si DOE projects. The reviewer encouraged the team to continue collaborating closely to avoid duplicating effort.

Reviewer 4:
The reviewer pointed out that the project teamed up with the strong research collaborators. However, it would be very beneficial to include a large battery manufacturer to work with more practical and cost-effective chemistries.

Reviewer 5:
The reviewer said that collaboration across the team is obvious and it is excellent. The reviewer pointed out that there appears to be some overlapping among the individual projects within SEISta and it might be more productive if tasks are better differentiated and coordinated in achieving the overall goals. Further enhancement may be achieved by including outside experts who work in an industry setting.

Reviewer 6:
The reviewer remarked that collaboration on the project within the national laboratory partners appears to be and should be able to be well-coordinated. Collaboration with university partners appears to be well-coordinated as well. The reviewer said that the absence of any partnership with an industrial electrolyte supplier may be of some concern and could limit maximum relevance.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that researchers identified the risks clearly and proposed a calculated mitigation strategy. The reviewer noted well-defined challenges and barriers with suitable risk mitigating proposals.

Reviewer 2:
The reviewer said that the work plan is relevant and clear.

Reviewer 3:
The reviewer commented that the plan to focus on the degree of stability of Si anodes and related aspects of SEI structure, composition, as well as presence of soluble compounds in the electrolyte, is sound. The reviewer pointed out that a greater focus on real-world Si anode surfaces (actual functional electrode active material particles or wires) may provide greater value if this is possible and does not detract from pursuing more fundamental findings.

Reviewer 4:
The reviewer pointed out that the team proposed an extensive list of future work that addresses the issues at hand. The reviewer noted how the work (like others in this program) is overly characterization-heavy, but there is a need to devote resources to understand the Si swelling and its mitigation to develop a practical solution.

Reviewer 5:

The reviewer said that overall, the proposed future work is logical and reasonable. The reviewer suggested that the surfaced physical and chemical properties of the current Si model system are better characterized. The reviewer cited as example what the nature is of the SiO_x on the surface. It is important that the model system bears resemblance to the working Si anode materials so that the learning is meaningful. The reviewer said that to stay relevant to the “real world” Si anode materials, other model systems may also need to be created and examined. The reviewer suggested that effort should also be introduced to transition the fundamental understanding gained from the model systems into practical cells for production.

Reviewer 6:

The reviewer observed a decent plan for future research but again it would be better to expand the work scope to include more materials for a practical electrode that may impact the analysis results.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that the project is very relevant to DOE’s overall objectives by providing insights into the SEI characteristics of Si that will, hopefully, allow development of durable Si electrodes.

Reviewer 2:

The reviewer commented that a Si-based anode is the choice for delivery of advanced Li-ion batteries with higher energy density and low-cost and have a great potential to meet DOE’s goals for EVs. The reviewer said that the fundamental electrochemistries in this project can better characterize a Si-based anode and the electrolyte interface providing clues on how to tackle the major life issues associated with Si-based anode.

Reviewer 3:

The reviewer found that the project supports DOE’s overall goals. Improving the performance of the Si anode material is critical in achieving the high-energy density needed in next-generation Li batteries.

Reviewer 4:

The reviewer said yes, the project supports overall DOE objectives in advancing the path towards an energy density increase via Si anode implementation.

Reviewer 5:

The reviewer noted that the project further highlights the huge challenge of stabilizing Si. Obviously, there are many different mechanisms and stabilization is very difficult. The reviewer said that work needs to continue for further understanding the surface chemistry if there is any hope of utilizing Si in high fraction.

Reviewer 6:

The reviewer remarked that most of DOE’s objectives are supported.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer believed the resources are sufficient to achieve the milestone in a timely fashion.

Reviewer 2:

The reviewer noted plenty of resources were identified using academia and DOE national laboratories to deliver timely milestones.

Reviewer 3:

The reviewer found that resources are in-line with work plan.

Reviewer 4:
The reviewer said that without knowing the funding level for individual projects, it is difficult to answer this question, but the overall SEISta program has sufficient resources.

Reviewer 5:
The reviewer noted enough resources for fundamental research with limited materials, but for broader research, the reviewer recommended the involvement of battery industries.

Reviewer 6:
The reviewer said that relative to other projects, the resources seem significant, but appropriate given the scope of activity and the number of partners.

Presentation Number: bat348
Presentation Title: Synthesis and Stability of Lithium Silicate and Its Interaction with the Solid-Electrolyte Interface (SEI)
Principal Investigator: Chris Apblett (Sandia National Laboratories)

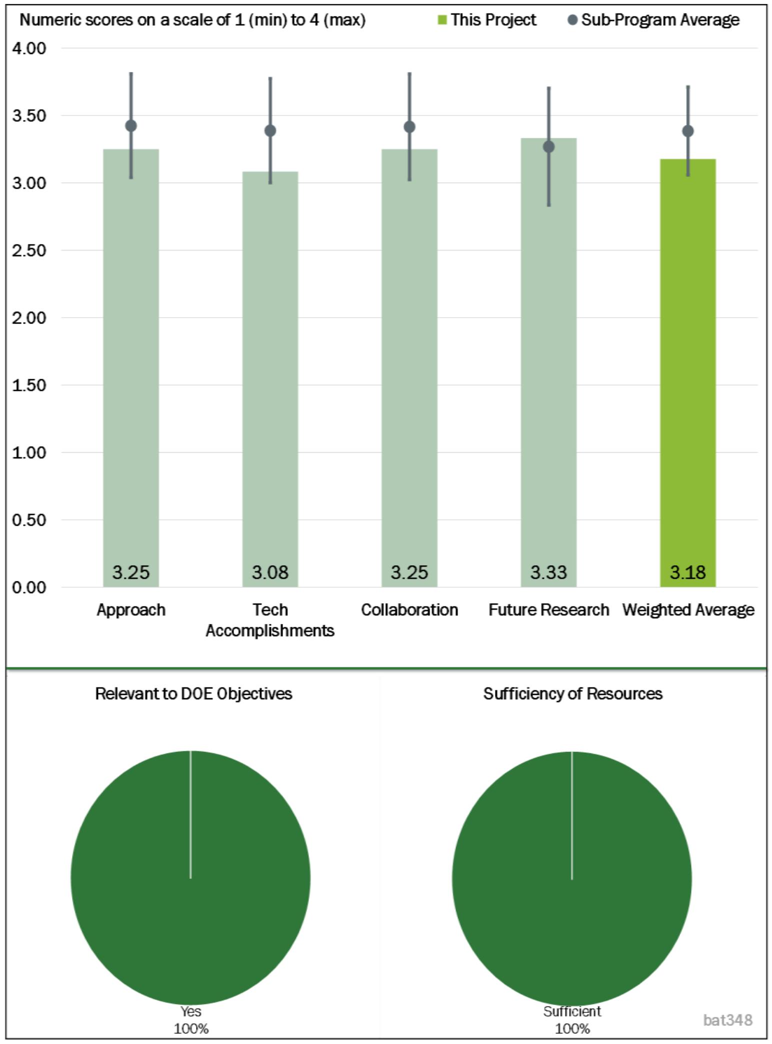

Figure 2-50 - Presentation Number: bat348 Presentation Title: Synthesis and Stability of Lithium Silicate and Its Interaction with the Solid-Electrolyte Interface (SEI) Principal Investigator: Chris Apblett (Sandia National Laboratories)

Presenter
Chris Apblett, Sandia National Laboratories

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer said that this project, as a part of the overall approach to characterize Si SEI, was primarily focused on the role of the silicates, if any. This compliments the work carried out by the other team members of this consortium.

Reviewer 2:
The reviewer commented that standardized test cells for reproducibility, and using easy to assemble architectures, are good approaches to understanding the underlying technical barrier. The reviewer noted a well-developed test and analysis plan.

Reviewer 3:
The reviewer remarked that resolving the importance of silicates in Si electrodes is critical and relevant. The reviewer said that this work is unique and focused.

Reviewer 4:
The reviewer noted a well-structured approach for characterizing Li silicate on a Si anode using chemical, mechanical, and electrochemical analyses.

Reviewer 5:
The reviewer found that this work seems to be generally focused on exploring silicate phenomena, which may not have been widely or conclusively observed or understood to date. So far, while it does not seem clear what the practical outcome of this will be, the reviewer acknowledged that the project is only at a midpoint. However, involved characterization of sample materials used by the rest of the SEISta team is worthy in itself

in supporting the best understanding of the entire SIESta team. The reviewer noted that elucidating the electrolyte decomposition products in the presence of uncycled electrodes must surely be of value to advancing specific understanding.

Reviewer 6:

The reviewer commented that the approach of studying model silicates to understand SEI is generally good and it complements the studies performed in the SEISta program. However, the reviewer was unclear how particular silicate model compounds (particularly chemical composition, structural properties, etc.) in this project were chosen. The reviewer wondered how relevant the results are without knowing these compounds even exist in the Si anode system.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that a thorough analysis of spectroscopic images and quantifiable data support the progress made toward the overall project. The reviewer said very informative and well thought out accomplishments towards the goal.

Reviewer 2:

The reviewer noted that the project has obtained a good amount of knowledge on some silicates. The project successfully used a number of techniques.

Reviewer 3:

The reviewer detailed how by using standard samples, the team carried out systematic studies to characterize the roles of the silicates in the SEI and measured their stability and reactivity in moisture and electrolytes using an array of analytical tools. While results are not fully unambiguous, they are quite useful in understanding whether the silicates play a dominant role or not. The reviewer found the mechanical response (modulus) studies during lithiation and de-lithiation especially insightful. The reviewer noted that impedance and SIMS results also shed further lights on the stability of the silicates.

Reviewer 4:

Progress to date appears to support the rest of the overall SIESta team, and furthers the general understanding of the SEI structure, layering, and physical properties.

Reviewer 5:

The reviewer commented that the work has identified many interesting questions so far. As the work progresses, the reviewer looks forward to more answers and solutions.

Reviewer 6:

The reviewer observed good initial observations on the behavior of various silicates with the presence of electrolytes. The reviewer expected more extensive investigations for a more robust explanation of changes during the tests (i.e., the sudden change in impedance).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the results demonstrate excellent collaboration among the project participants.

Reviewer 2:

The reviewer said that collaboration with national laboratories seems to be effective, in particular, the design of the test cell for characterizing target materials.

Reviewer 3:
The reviewer remarked there is strong collaboration across the team.

Reviewer 4:
The reviewer observed reasonable collaboration between other DOE projects. The reviewer remarked that increased interaction with BAT344 for experimental verification of models, and with BAT345, which has similar work, could be more explicit.

Reviewer 5:
The reviewer said that most of the projects are well-coordinated between DOE national laboratories and academia. Involving an industry partner will add real-time complexity to the project and will help to find alternatives effectively.

Reviewer 6:
The reviewer said that collaboration on the project within the national laboratory system partners, appears to be and should be able to be well-coordinated. The reviewer noted that collaboration with university partners appears to be well-coordinated as well. The reviewer pointed out that the absence of any partnership with an industrial electrolyte supplier may be of some concern and could limit maximum relevance.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the proposed future research, including an emphasis on characterizing the sudden rise in impedance/compliant layer, and elucidating the kinetic parameters, appear good. The reviewer especially liked the team's use of the Milestone Chart, which gives a quick overview of the remaining tasks in this project. The reviewer suggested that other team-members use such a chart to help the reviewers better appreciate the work scope.

Reviewer 2:
The reviewer commented well thought-out, broad-based future research plans to support the challenges and barriers. The reviewer commented that the proposed future research clearly identified all the risks and remedial plans.

Reviewer 3:
The reviewer said that most of essential future works were well-planed and described, including the temperature effect on SEI formation on the Si anode, which other research groups did not indicate.

Reviewer 4:
The reviewer pointed out that temperature-based soaking experiments may be challenging to configure but should be valuable, and remarked that the intent to work with powder research efforts to verify phenomena in real powders is an excellent aspect of planned future work.

Reviewer 5:
The reviewer said that overall, the proposed future work is logical and reasonable. The reviewer suggested that more effort be put into real-time detection of silicates to answer questions such as whether they form, what they are, etc. The reviewer thought that perhaps new techniques can be developed to better detect silicates. Without better definition, this reviewer explained that it is difficult to construct silicate model systems and carry out detailed studies that would provide researchers with much needed insights.

Reviewer 6:
The reviewer said that future work is clear and relevant. The reviewer suggested that more details and developing a method to allow experimentation during electrochemical lithiation would be useful.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that as with the other projects in this consortium, this project has definite relevance to DOE's overall project to develop a high-energy density battery.

Reviewer 2:
This is another piece of a big puzzle in characterizing a Si-anode and finding the root causes of its aging mechanisms to deliver a robust high-energy density Li-ion battery technology. The reviewer said that like other projects, it would be great if other electrode components are included in the research for their effect on the presence of SEI layer on Si anode.

Reviewer 3:
The reviewer said that some of the projects list the common DOE objectives of cost, performance, and safety risks. The reviewer said that safety risk is not well addressed in this project, but performance objectives are well met.

Reviewer 4:
The reviewer said that understanding the role of silicates on Si SEI is very relevant and necessary.

Reviewer 5:
The reviewer found that the project supports the overall DOE objectives. Improving the performance of Si anode material is critical in achieving the high energy density needed in the next generation Li batteries.

Reviewer 6:
The reviewer agreed yes, the project supports overall DOE objectives in advancing the path towards energy density increase via Si anode implementation.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer believed the funding is sufficient.

Reviewer 2:
The reviewer noted good collaboration to achieve timely milestones.

Reviewer 3:
The reviewer said that resources are in line with the work plan.

Reviewer 4:
It seemed to the reviewer that the resources are enough for the first year of research. The reviewer said that if the collaborative effort is extended with a material manufacturer (who may provide more commercial baseline material) and/or cell manufacturer (who can provide with more practical electrode), it would be very promising project.

Reviewer 5:
The reviewer said that the level of funding for this project was unclear, but the overall SEISta program has sufficient resources.

Reviewer 6:

The reviewer commented that relative to other projects, the resources seem significant, but seem more than sufficient given the scope of activity and the number of partners.

Presentation Number: bat349
Presentation Title: Research Facilities Support
Principal Investigator: Kyle Fenton (Sandia National Laboratories)

Presenter

Kyle Fenton, Sandia National Laboratories

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project has as its core focus developing and processing a Si anode that will be a viable candidate as a durable anode for high-energy Li-ion batteries. It is a multi-lab effort combining complementary strengths of the various national laboratories. The tasks are well-thought out and comprehensive except for the fact that there is too much emphasis on characterization.

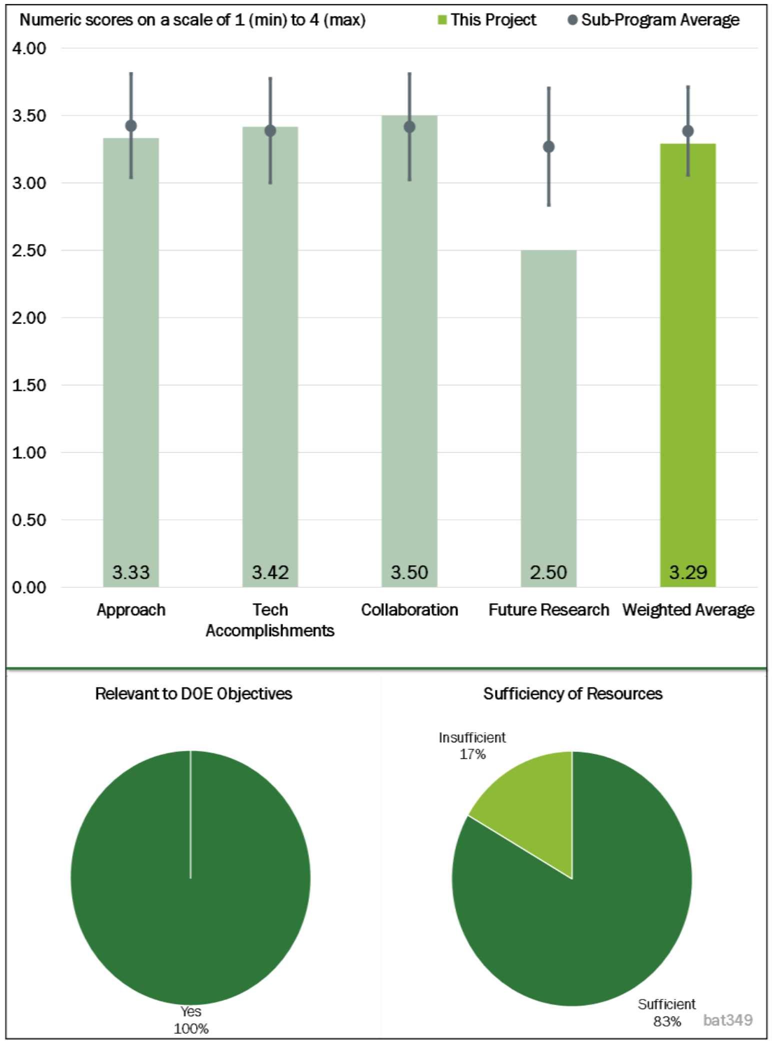

Figure 2-51 - Presentation Number: bat349 Presentation Title: Research Facilities Support Principal Investigator: Kyle Fenton (Sandia National Laboratories)

Reviewer 2:

The reviewer observed clearly identified roles and responsibilities of research facilities' support to carry out the DOE technical barriers associated with battery development and overall DOE objectives. Further, this reviewer remarked that capability and feasibility are addressed very well.

Reviewer 3:

The reviewer said that the improved facilities are having a positive impact on all of the DOE Si work.

Reviewer 4:

The reviewer commented that the project takes in a wide swath of responsibility for support of Si activity in general and seems well-designed considering the breadth of activities and facilities.

Reviewer 5:

The reviewer said that the main approach of ANL's CAMP facility was informed by the change in direction of electrode design with a higher amount of Si content and a lower level of lithiation. However, the reviewer found that the target loading level (mAh/cm^2) of the electrodes in this project is not practical and even lower than state of the-art. The reviewer suggested that a target for the loading level should be newly set up and clearly indicated for better practicality.

Reviewer 6:

The reviewer found that the approach is excellent. This is a great effort in utilizing DOE's existing large facilities and also providing an anchor for the multi-institutional projects within the Si program. The reviewer commented that the changes in direction, going from low amounts of Si and a high level of lithiation to high amounts of Si and low levels of lithiation, is a good choice. The reviewer pointed out that industry is active in pushing higher Si and it is important that a large Si program such as this one is involved in the same space. The reviewer would like to see a better connection to industrial Si anode materials. Ideally, selection of industrial material should be performance- or metrics-based rather than availability-based (as the case for the current arrangement). The reviewer understands that sometimes it is limited by availability, but because there are a number of companies producing a high-performing Si anode at this point, it seems important to stay relevant.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the facility is excellent and still improving.

Reviewer 2:

The reviewer observed a very good analysis to identify the impurities in the Si materials. The reviewer said that it will be beneficial to highlight what performance is specifically expected instead of broad-based expectation.

Reviewer 3:

The reviewer pointed out that the data obtained on the processing of Si materials at the pilot scale, an important aspect of the work carried out in this project, showed the sensitivity to moisture/air, which is very useful. Researchers should note here, though, that it is unclear how much of these lessons learned can be transferred to Si materials that eventually become suitable for use as a durable anode. The reviewer commented that data from safety tests are very instructive and quite valuable (the reviewer did not see the capacity of the cells). Many researchers are not very aware of such challenges from the open literature.

Reviewer 4:

The reviewer said that this program has a range of milestones and broad work scopes. The reviewer found that overall, the team reported decent progress through technical facility support covering a range of milestones related to integrated activities.

Reviewer 5:

The reviewer said that significant progress has been made on understanding how processing leads to different interface terminations. The knowledge is very important in enabling high-quality Si anode materials. The reviewer observed a range of thermal behaviors in the studies. The reviewer would recommend that the group better characterize Si surface properties so that better correlation can be established. The reviewer would also like to see more effort to transition the knowledge gained from these specific studies into practical cells for production. The reviewer suggested that bringing in an industry partner would greatly strengthen the effort.

Reviewer 6:

The reviewer commented that while creating significant challenges, the findings regarding Si-based cell abuse response in accelerating rate calorimeter testing are critical to moving forward with significant Si-containing cell chemistries in a best-educated basis for the future. Additionally, the reviewer noted that gas generation studies during slurry mixing provide important insight into one novel area of the overall picture of challenges in moving forward with significant Si-containing cell chemistries.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the project had excellent collaboration among the consortium members.

Reviewer 2:

The reviewer remarked that collaboration with various national laboratories is the key for the success of this project, and related projects have already demonstrated the strong collaboration leading to fruitful outcomes from fundamental research on the Si-anode

Reviewer 3:

The reviewer remarked that most of the DOE national laboratories are involved in this project; this is a good coordination effort.

Reviewer 4:

The reviewer said that coordination within the Silicon Deep Dive effort is excellent.

Reviewer 5:

The reviewer found that collaboration across the project team is very strong. There is clear coordination among the institutions involved in the program.

Reviewer 6:

The reviewer commented that collaboration on the project within the national laboratory system partners appears to be and should be able to be well-coordinated.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that proposed work, albeit very generic, is at the heart of the issue. (Interestingly none of the other project teams has specifically mentioned these topics as highlighted here). The reviewer saw as a challenge that all the other national laboratories are focusing primarily on SEI characterization and related topics. The reviewer remarked that none of the projects focused directly on how to contain swelling and make the cells durable. The reviewer said that needs to be the core effort going forward now that the characterization studies have made tremendous progress.

Reviewer 2:

The reviewer said that the future direction on synthesis is clear, but more details on other work would be appreciated.

Reviewer 3:

The reviewer said that the future research plan is not mentioned in this project.

Reviewer 4:

The reviewer said that only remaining challenges and barriers are available, and no information on proposed future research was provided in detail.

Reviewer 5:

The reviewer said that no future work was presented, and the reviewer was not sure this project is continuing.

Reviewer 6:

The reviewer said that although proposed future work does not appear to be specifically described in most areas, an assumed intent for continuation of existing work and continuation of general support for the SIESta project would be good, and is assumed in the absence of any particular descriptions.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer pointed out that without excellent research facilities, progress would not be possible. This project is relevant and necessary.

Reviewer 2:

The reviewer commented that the project is highly relevant to DOE's overall objectives of safe and cost-efficient high-energy battery by addressing issues that will enable the development of a high-capacity, durable Si anode.

Reviewer 3:

The reviewer said yes, the project supports overall DOE objectives in advancing the path towards an energy density increase via Si anode implementation.

Reviewer 4:

The reviewer remarked that research facilities support is one of the key parameters for success of battery projects to tackle the issues related to advanced battery materials and cell design.

Reviewer 5:

The reviewer said that the project supports DOE's goals of improving the performance of Si anode material to achieve high energy density.

Reviewer 6:

The reviewer said that all the DOE national laboratories have a common mission to fulfil DOE's objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that relative to other projects and given the scope of project activity, the resources may appear to be insufficient.

Reviewer 2:

The reviewer said that resources are sufficient except for the electrode fabrication area. The reviewer recommended benchmarking with state-of-the-art cells for more practical targets in terms of electrode design and material selections.

Reviewer 3:

The reviewer said that the resources should be sufficient to complete the tasks on schedule.

Reviewer 4:

The reviewer commented that DOE national laboratories are equipped with the best resources both tangible and intangible to achieve the milestones and to address the technical barriers in a timely fashion.

Reviewer 5:

The reviewer found that resources are in-line with work plan.

Reviewer 6:

The reviewer commented that the funding level for this project was not provided but the Si program overall has sufficient resources.

Presentation Number: bat350 Presentation Title: Electrode Characterization and Analysis Principal Investigator: Daniel Abraham (Argonne National Laboratory)

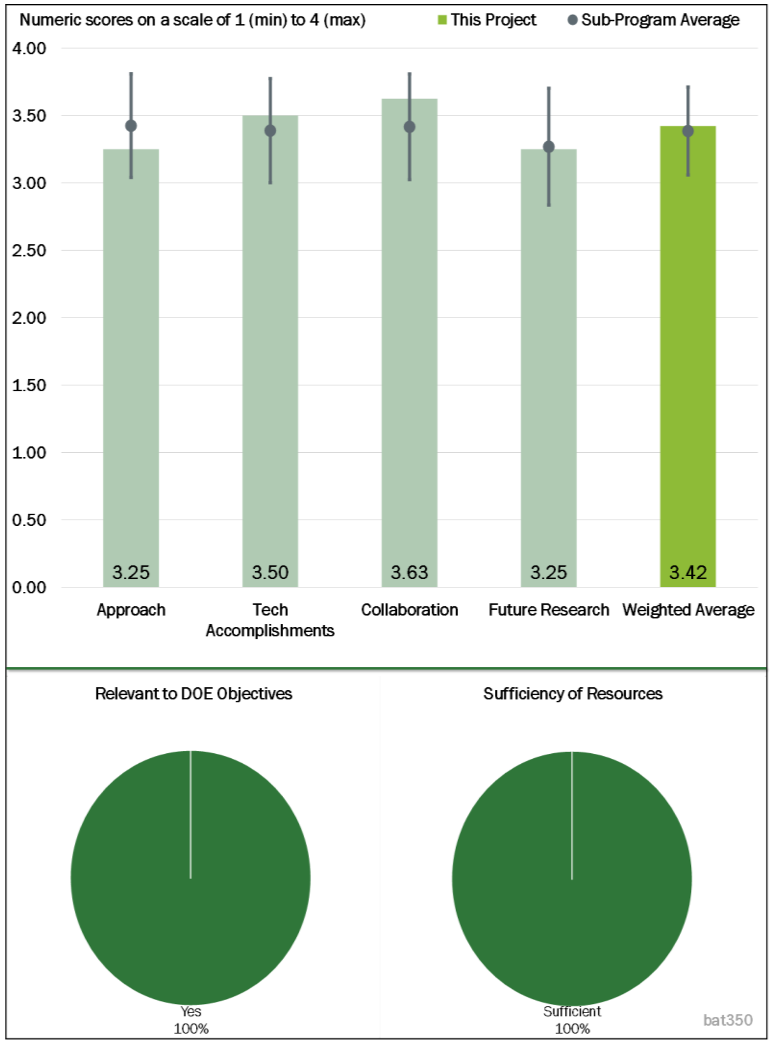

Figure 2-52 - Presentation Number: bat350 Presentation Title: Electrode Characterization and Analysis Principal Investigator: Daniel Abraham (Argonne National Laboratory)

Presenter

Steve Trask, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that advanced anode development and characterization is critical to meet NG Li-ion specific energy, energy density, cost, and life goals. Subsequently, the reviewer noted a well-defined, overall approach for the remaining Si anode solutions.

Reviewer 2:

The reviewer noted that this was a huge program and required a lot of collaborations. This project is specifically focused on electrode characterization and analysis, and the approach is well designed and will make a great contribution for this whole Si program.

Reviewer 3:

The reviewer said that overall, the approach is very comprehensive and multiple techniques are used to characterize the various issues. The reviewer said that, however, there is little discussion of the meaning and impact of the findings.

Reviewer 4:

The reviewer said that this team is spending $3.6 million per plus assistance from all of the fully funded facilities at ANL to make Si-Gr 15/73 electrodes and determine their functionality. The reviewer reported that there are two investigators listed on the title slide listed, but no one can tell whether this is the work of two investigators or five national laboratories. The reviewer noted that 20 milestones and a long list of activities are mentioned. The reviewer described the presentation as very confusing. For this group of presentations, the focus of the effort being presented does not start until the Approach slide. It is here that one finally discovers that this presentation will be an assessment of the performance of a Si/Gr electrode prepared with two different binders with regard to life, activity, and heat effects.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer believed that the work done is systematic and directly addresses project goals. Tracking the lithiation state for Si and Gr, binder and coating studies, capacity loss, and gassing investigations are all very relevant to developing efficient and effective characterizations for Si-containing materials.

Reviewer 2:

The reviewer said that of the tasks discussed in the bulk of the presentation, which the reviewer assumed were primarily performed by Trask and Abraham, good progress has been made in assessing life with regard to calendar and cycling, assessing heat release with temperature, Gr activity, and the contrasting effect of binders and solvent on performance. The reviewer thought it was interesting to see that an electrode that starts from a more uniform composition did not necessarily finish with a more uniform composition.

Reviewer 3:

The reviewer pointed out that the milestone describes the technical accomplishments for each national laboratory.

Reviewer 4:

The reviewer found that the reported work is very interesting, especially that related to relative lithiation and the effect of binders and coating. The reviewer inquired how these results depend on the specific microstructure of the C/Si composite. The reviewer said that more characterization at the microstructure level would be useful.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that collaboration among DOE national laboratories is excellent.

Reviewer 2:

The reviewer said that the team has diverse expertise and access to excellent facilities. There is an apparent very good coordination of efforts.

Reviewer 3:

The reviewer remarked that coordination and collaborations are very good for this big Si program.

Reviewer 4:

The reviewer said that although assuming that these are the two main investigators, there is clearly plenty of help in obtaining materials, access and assistance with several pieces of equipment. The reviewer found that despite addressing several topics, much has been learned.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that proposed future work is focused on areas highly relevant to achieving DOE goals. These include identifying Si volume change during cycling, improving cycle life aging results, and investigating Si properties to minimize energy release and gas generation. The reviewer is also pretty excited to see the future results by using in situ Raman techniques.

Reviewer 2:
The reviewer said that optimizing electrolyte and electrode composition will help with life expectations.

Reviewer 3:
The reviewer remarked that the scope is too broad, and that more focus on specific questions may be useful. For example, the future work includes analysis of many different compositions, but researchers still do not completely understand the results at one fixed composition and how they could be dependent on electrode processing, specific chemistries, etc.

Reviewer 4:
The reviewer expressed uncertainty about what researchers will learn from operando experiments of measuring lithiation of Si as a function of Si content. The reviewer was not sure what the project team is doing with the additional inhomogeneity mapping. Hopefully, this will be combined with fabrication techniques to eliminate inhomogeneities. The reviewer expressed uncertainty about how the project team plans to minimize energy release and gas generation.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that finding a way to increase the anode specific capacity to increase energy density clearly supports DOE’s objectives.

Reviewer 2:
The reviewer remarked that understanding the mechanism of Si anodes in Li-ion batteries is really important for DOE objectives.

Reviewer 3:
The reviewer commented that the advanced anode containing Si will meet DOE energy and life targets.

Reviewer 4:
The reviewer said that this project supports DOE objectives of advancing higher capacity anode technologies.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that resources are very reasonable.

Reviewer 2:
The reviewer remarked that resources are sufficient for this project.

Reviewer 3:
The reviewer commented that $3.6 million spending and DOE national laboratory resources should be able to support the work described in the project.

Reviewer 4:
The reviewer remarked that there is a bunch of money and physical resources being applied to develop an electrode with some Si in it. This appears to be a decent effort, but there is no clue as to how many PI’s work is being put forth in this particular presentation and what fraction of the time of the funded facilities is being occupied by this project. The reviewer said that if there was a deadline to make some defined progress, one might be able to assess how well resources are being distributed.

Presentation Number: bat351
Presentation Title: Active Particle Studies
Principal Investigator: Baris Key (Argonne National Laboratory)

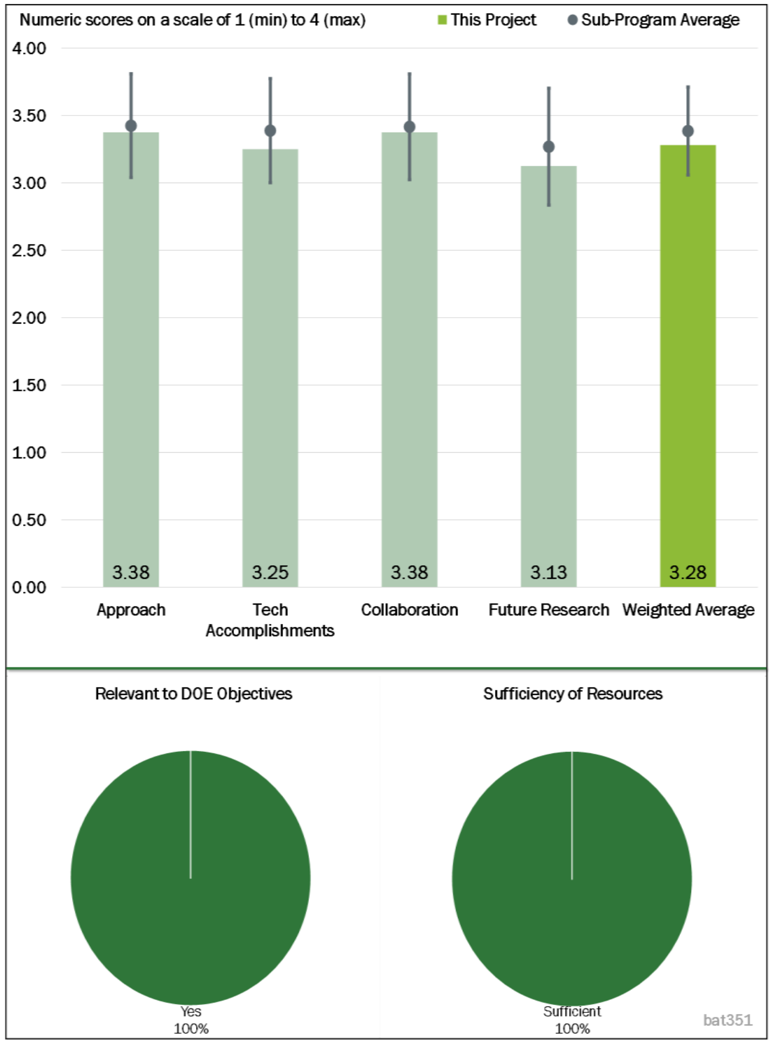

Figure 2-53 - Presentation Number: bat351 Presentation Title: Active Particle Studies Principal Investigator: Baris Key (Argonne National Laboratory)

Presenter

Baris Key, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the project is utilizing local structure probes (NMR, FTIR, and Raman) along with diffraction is a great approach to analyzing Si materials. Li_7Si_3 is also a good start point.

Reviewer 2:

The reviewer commented that finding the most suitable Si powder, which will provide a long life and minimum self-discharge, is a good approach.

Reviewer 3:

The reviewer said that studying the reactivity of the active particles with the electrolyte and binders is useful. The reviewer pointed out that because the chemistry of these materials is very sensitive to the environment, in the context of the overall project it would be useful to consider the presence of C.

Reviewer 4:

The reviewer said that after reading the same four boiler plate slides for five presentations, reviewers finally get to the part of the presentation that finally speaks specifically to what will be seen for the next 20 minutes. It was extremely difficult for this reviewer to read the approach and have any idea if it supports what was about to follow. As it turns out, the investigator used NMR, FTIR, and Raman to study the degree of reactivity of Si compounds in the presence of different materials.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer acknowledged that there are a lot of technical accomplishments in this project. However, the reviewer noticed the investigation of triglyme-based electrolytes in this project, which is not a good choice for continuing studies. The ether is well-known for its voltage instability in Li-ion batteries.

Reviewer 2:

The reviewer remarked that studying the reactivity of the active materials (specifically Si alloys) is definitely useful, and the study is comprehensive. The reviewer pointed out that because many of these analyses have been previously done in several laboratories, it would be useful to have a comparison.

Reviewer 3:

The reviewer noted that the project utilized NMR to detect reaction of different Si compounds at different lithiations with different environments. This helped in understanding reactivity in air, against different binders, and with different components of the electrolyte. The reviewer said that the researchers need to figure out the inconsistencies between this work and results found in electrochemical cells.

Reviewer 4:

The reviewer said that the tools to study the reactivity are well applied. However, quantification to meet the 1,000 cycle and less than 1%/month self-discharge is very important to find optimized raw materials.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked overall, this is a part of big program, which has really great collaboration.

Reviewer 2:

The reviewer said that collaboration among DOE national laboratories is working well.

Reviewer 3:

The reviewer said that collaboration among the national laboratories is very good.

Reviewer 4:

The reviewer commented that the investigator effectively collaborated with a number of researchers, including those able to make cells with different active and inactive components and test and cycle cells. However, a discussion between the research results found here versus other aspects of this project appears to be lacking.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer suggested that if this project is also considering the C/Si electrodes, then the contribution of C to the reactivity and stability should be studied. The reviewer concluded that proposed future research is overall very good.

Reviewer 2:

The reviewer said that the researcher intends to continue to investigate the reactivity of different systems and start to look at products from the reactivity of different electrolytes. The reviewer pointed out that the project team hopes to use this in the development of better electrolytes.

Reviewer 3:
The reviewer found that long-term future research seems reasonable, and the reviewer prefers limited studies for triglyme-based electrolytes.

Reviewer 4:
The reviewer said that the future studies should be aligned with the DOE cycle life and self-discharge requirements.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said great support for DOE objectives.

Reviewer 2:
The reviewer said that the results of the study will help to increase cycle life and calendar life.

Reviewer 3:
The reviewer said yes, because it focuses on higher capacity Si anodes.

Reviewer 4:
The reviewer detailed that by understanding the reactivity of Si with different components, the team may be able to develop a system that has the right level of reactivity that also leads to passivation. This is critical in developing the high capacity loading of Si as an anode material.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that $3.6 million and DOE national laboratory resources are sufficient.

Reviewer 2:
The reviewer said that resources appear sufficient.

Reviewer 3:
The reviewer commented that the resources are sufficient.

Reviewer 4:
The reviewer found it impossible to comment here because the distribution of resources is so vague (and deliberately so).

Presentation Number: bat352
Presentation Title: Active Materials Advancements
Principal Investigator: Zhengcheng (John) Zhang (Argonne National Laboratory)

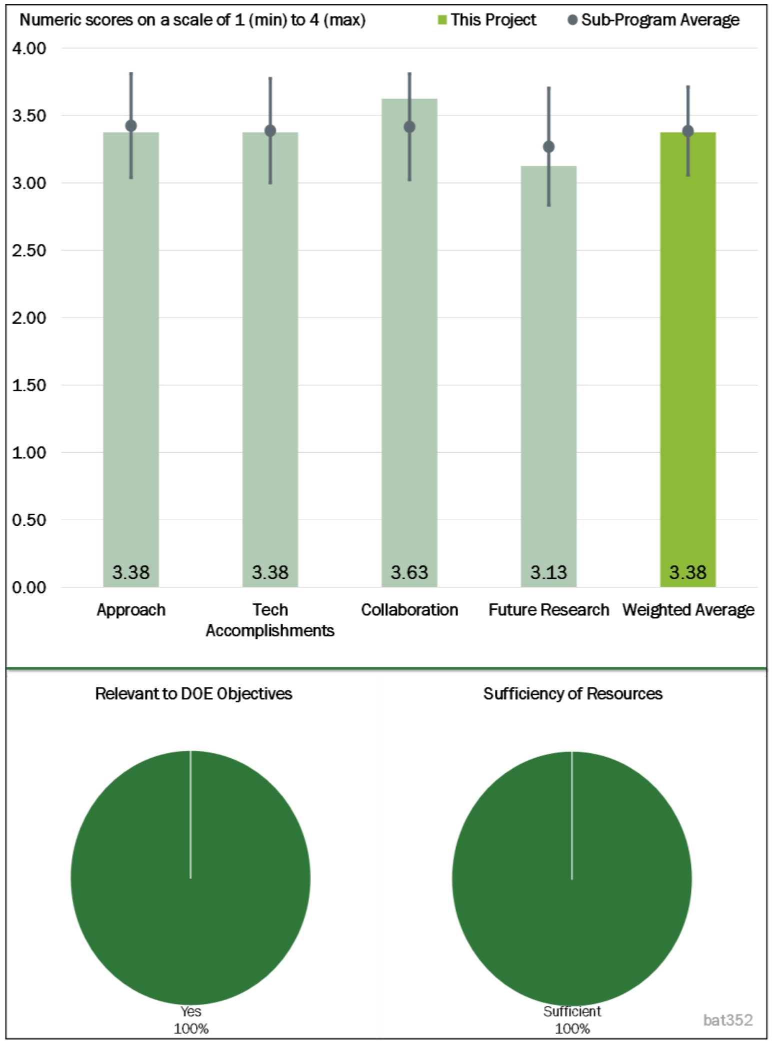

Figure 2-54 - Presentation Number: bat352 Presentation Title: Active Materials Advancements Principal Investigator: Zhengcheng (John) Zhang (Argonne National Laboratory)

Presenter

Zhengcheng (John) Zhang, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the group is synthesizing a myriad of Si materials, each with its own unique means of improving cyclability, to understand the benefits of different configurations.

Reviewer 2:

The reviewer said that a variety of approaches are used apparently to elucidate the effect of particle morphology. The reviewer recommended that some outline of the objectives and long-term goals would be useful.

Reviewer 3:

The reviewer said that the Si advanced anode materials optimized for swelling will improve the life of the Li-ion cells

Reviewer 4:

With so many techniques have been applied in this project, the reviewer thought the approach was well-outlined, difficult but feasible, and aligned with other focuses in this big Si program. The reviewer said that if successful, the effort will result in a successful application of a Si anode in next-generation high-energy Li-ion batteries.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer pointed out that a lot of data have been generated; some of it duplicates previous data reported by these groups and other national laboratories. A one-page summary of current conclusions and new contributions to the understanding of Si anodes would be helpful.

Reviewer 2:
The reviewer noted that there are enormous works focused on Si/SiO modifications in this project, which are vital to enable high-capacity Si anodes in next-generation Li-ion batteries. The reviewer pointed out that the electrolyte and additive work related to SEI formation is another key factor to enable a Si-based anode. The reviewer believed this project is on the right track and made great progress in this period.

Reviewer 3:
The reviewer said that the team synthesize a number of materials, provide a schematic of what was made, and then provided good evidence that what was made was what the team hoped to make. The reviewer pointed out that the team then provided testing data with comparable chemistries. The reviewer was unsure why the team show cycling against Li but not a lot of cycling in a full cell, and was unsure how the team assessed CE when there is capacity fade.

Reviewer 4:
The reviewer said that the cycle life test should be continued for more than 1,000 cycles before concluding on the stability of Si anode, and the charge profile should include the fast charge requirements.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said that collaboration and coordination among six national laboratories is great for this big program.

Reviewer 2:
The reviewer remarked excellent collaboration is working among the DOE national laboratories.

Reviewer 3:
The reviewer said that there is an extensive collaboration between participants in the project.

Reviewer 4:
The reviewer observed a lot of synthesis, a lot of SEMs, a lot of spectroscopic data, and a lot of cycling data. The reviewer said that this takes a lot of collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the proposed work is interesting. It would be good to establish the role of the C/Si interactions.

Reviewer 2:
The reviewer said that there are so many good future research directions for this program. The reviewer would like to know whether all the partners in this program can use the same baseline materials from CAMP, which can make the comparison of performance improvement much clearer. The reviewer also said that an

impedance study is also a good tool to evaluate different Si materials performance, which may deserve a more important role for the future research in this program.

Reviewer 3:

The reviewer said that future optimization should be aligned to the lifecycle of more than 1,000 cycles and fast-charge capability of 4C charge rates.

Reviewer 4:

The reviewer was unclear how the team selected the materials that are going to be pursued next. The reviewer said that it would be nice to see some of the diagnostics and efforts from SEISta have some influence on the selection.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer remarked that development of high-energy cells with Si-based anodes is a great support for DOE objectives.

Reviewer 2:

The reviewer agreed that the work is relevant to the development of high-capacity anodes.

Reviewer 3:

The reviewer commented that figuring out how to get Si to cycle certainly supports DOE objectives of increasing energy density.

Reviewer 4:

The reviewer remarked that the optimized electrode material will increase the sp. energy, energy density, and life of the Li-ion cells.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that resources are sufficient.

Reviewer 2:

The reviewer found that $3.6 million should be sufficient to support the work described here.

Reviewer 3:

The reviewer said that the facilities and resources are excellent.

Reviewer 4:

Like every presentation given in this block, the reviewer had no clue how much this group receives relative to any other group. Apparently, there is no oversight of how funding is distributed.

Presentation Number: bat353
Presentation Title: Crucial Supporting Materials Advancements
Principal Investigator: Gao Liu (Lawrence Berkeley National Laboratory)

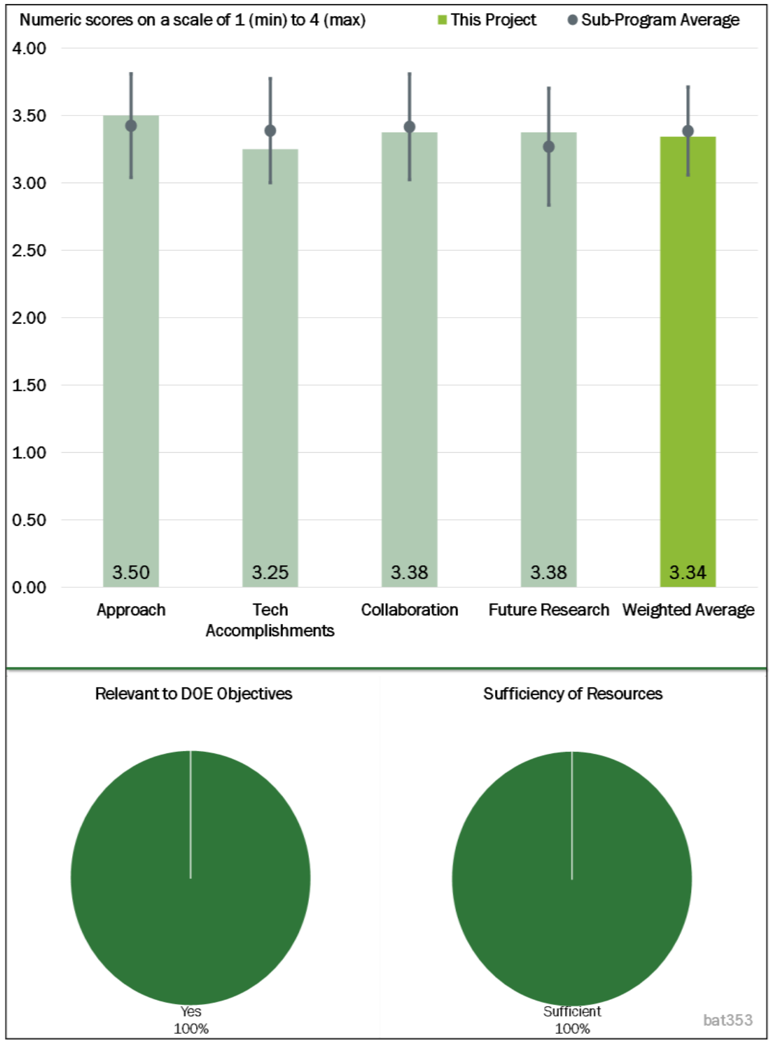

Figure 2-55 - Presentation Number: bat353 Presentation Title: Crucial Supporting Materials Advancements Principal Investigator: Gao Liu (Lawrence Berkeley National Laboratory)

Presenter

Gao Liu, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer appreciated the systematic approach taken by the investigators. The team appeared to start from a baseline chemistry and build on it as the team learned how it was performing.

Reviewer 2:

The reviewer pointed out that identifying additives, binders, and pre-lithiation techniques to increase the cycle life and reduction of swelling will help DOE to meet its energy goals.

Reviewer 3:

The reviewer observed an excellent approach by combining of the development of electrolyte additives, electrode binder, and Li inventory to support this Si anode program.

Reviewer 4:

The reviewer said that the proposed approach is very appropriate. Because a lot of work has been done inside and outside the program, comparison to previous reports on this topic should be essential.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the project team is investigating several ways to improve the cycling of Si and understand effects in full and half cells. Once a material is tested, the team makes systematic changes to improve it.

Reviewer 2:

The reviewer commented that all the technical accomplishments are still in early stage; most investigations are focused on understanding the mechanisms between Si and other components in the cell. The reviewer saw a lot of progress in this project, especially the Li inventory part, and really wants to see the difference among various cathode materials. The reviewer noted that if this study can be successful in the near future, the application of Si material in a high-energy system can be really facilitated.

Reviewer 3:

The reviewer pointed out that further research on identifying optimized additives, binders, and pre-lithiation strategies will lead the cell development to meet DOE goals.

Reviewer 4:

The reviewer noted that the project has generated a lot of data, and the study of binders seems interesting and useful. The reviewer suggested that more integration with the other (BAT350, 351, 352) projects would be useful.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that there are researchers thinking of new chemistries, others making new chemistries, others scaling up new chemistries, electrodes being fabricated, and cells being tested. The reviewer concluded a well-coordinated team.

Reviewer 2:

The reviewer noted that coordination and collaborations are very good.

Reviewer 3:

The collaboration among the national laboratories will lead to improved life of Li-ion cells.

Reviewer 4:

The reviewer said that more interaction with the other teams is desirable, so the project can accomplish the stated objectives.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the additives, binders, and pre-lithiation will play a critical role in Li-ion cell improvements.

Reviewer 2:

The reviewer remarked that the proposed study of binders and additives could be key for the stabilization of the anode.

Reviewer 3:

The reviewer observed well-designed proposed future research with a lot of detailed information. This is really helpful for handing such big program with so many collaborators.

Reviewer 4:
The reviewer commented that there are a lot of materials being considered, some new, some improvements of others. The reviewer expressed uncertainty why so much work is needed in pre-lithiation. This is not the problem; consumption of Li with cycling is. The reviewer stated we know how to do pre-lithiation.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer found that the project supports DOE's objective of developing high-capacity anodes.

Reviewer 2:
The reviewer believed the development of Si anode materials is super important for the next-generation high-energy Li-ion batteries. The electrolyte and additive development is a key factor to enable Si materials and deserves much more attention than it currently has.

Reviewer 3:
The reviewer remarked that success in this project will help with getting more Si in the anode to improve capacity density and thereby energy density.

Reviewer 4:
The reviewer said that the reduction in swelling and improvement in electrode behavior will help to meet DOE goals.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked resources and facilities are excellent.

Reviewer 2:
The reviewer said resources are sufficient.

Reviewer 3:
The reviewer stated that DOE resources for the R&D work are sufficient.

Reviewer 4:
The reviewer said no clue, and that one giant number was given for the entire project.

Presentation Number: bat355
Presentation Title: Development of High-Performance Lithium-Ion Cell Technology for Electric Vehicle Applications
Principal Investigator: Keith Kepler (Farasis Energy)

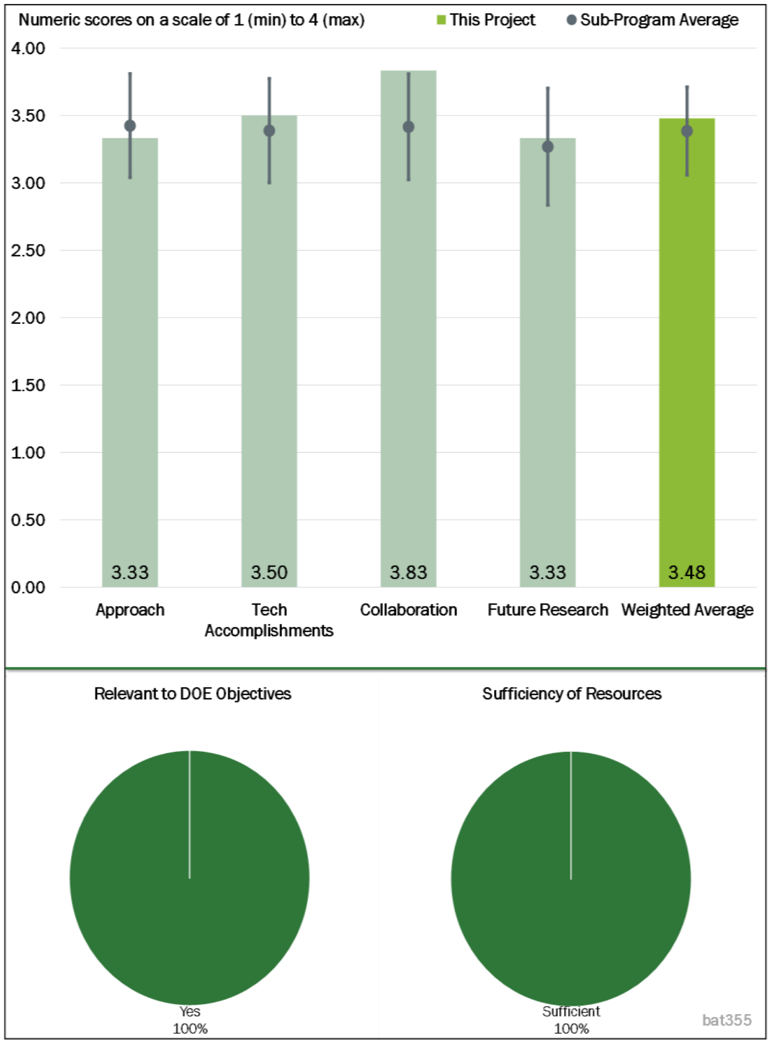

Figure 2-56 - Presentation Number: bat355 Presentation Title: Development of High-Performance Lithium-Ion Cell Technology for Electric Vehicle Applications Principal Investigator: Keith Kepler (Farasis Energy)

Presenter

Madhuri Thakur, Farasis Energy

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that although the electrode active material couple is not novel, the project is addressing many challenges related to successfully implementing Ni-rich cathodes and Si-C anodes for long-term performance, such as stabilizing the anode and cathode SEI layers. This project is well-designed and laid out given that there are so many variables and test matrix materials. The reviewer said the project has clear milestones and deliverables, and relevant pouch cell cycling performance evaluation. The reviewer expressed as a concern the impedance problems at the cathode with the Li-iron oxide source, but there is a clear plan in future work to understand this phenomenon. The reviewer said that it would be good to see calendar life testing as part of the future work for this/these electrochemical couple(s).

Reviewer 2:

The reviewer detailed that the project aims to address the key barrier to achieve high-capacity, long cycle life, and safer Li-ion cells. The reviewer summarized that Li-ion battery performance is improved via developing high voltage (≥ 4.6V Ni-rich/Mn-rich cathode composites, high-performance Si-based anode, and fluorinated solvents and stabilizing additives/salts for the electrolyte. The composition and structure of both anode and cathode materials are not described. The reviewer was unclear what specific strategy has been devised to realize the goal of project.

Reviewer 3:

The reviewer detailed that the proposed approach integrates a high-energy cathode, Si composites, and optimized electrolyte into pouch cell format for evaluation. The Li source materials are also validated in cathode. The reviewer said that although the PI mentioned a target on the cell-level energy when screening the cathode and anode, it is not clear what the specific areal capacities of both cathode and anode need to reach. In addition to the specific capacity of active materials, the electrode-level porosity, electrode press density, etc. all play key roles in determining the cell-level energy. The reviewer said that the PI needs to provide a number of areal capacity and mass loading that all the research will be built on.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that there has been a significant amount of progress, especially for a new start, on all major technical categories. However, the anode conductive additives do not seem to improve performance over the control cell.

Reviewer 2:

The reviewer said that the investigators have finished the evaluation of the high Ni-content based cathodes and different materials options for Si anodes and the optimized electrolyte. The high-energy cells exhibit energy density of greater than 300 Wh/Kg. The reviewer said that the cyclic testing data should be provided, and the slides should give a detailed description of the difference of the developed anode and cathode from those previously reported.

Reviewer 3:

The reviewer said that the team has evaluated 12 cathodes, 4 anodes and down-selected A1 and C1 for a Gen1 deliverable. Electrolytes and C additives are also evaluated to improve the cell performances. The reviewer was unclear how much Li resource needs to be used in Gen 1. To get a maximum utilization of the anode materials, the percentage of Li source in the cathode will be adjusted to compensate the first cycle loss. However, it is unknown what the ratio of negative to positive electrodes (N/P) is in the Gen 1 cell. The reviewer said that incorporating a sacrificial source in the cathode adds on more "parasitic." weight and sacrifices the cell-level energy. The reviewer was unclear how the team will balance the cell energy and first cycle loss. The single or double layer pouch cells are tested in flooded electrolytes. The reviewer asked if the author calculated how much electrolyte will be actually incorporated the in Gen 1 cell. If the single or double layer pouch cells are tested under such lean electrolyte conditions, the reviewer asked whether the cycling will last for the same few hundreds of cycling.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that collaboration with ANL and LBNL have benefited the project.

Reviewer 2:

The reviewer pointed out that ANL's contribution is quite clear in this project, i.e., to develop a sacrificial Li-source for Si anode. The reviewer noted that LBNL is helping on the high-voltage conductive additive for this project.

Reviewer 3:

The reviewer said that collaboration is outstanding in this project. The PI has covered active material suppliers, inactive material suppliers, cell manufacturing, and strategic national laboratory partners. However, the manufacturing scale-up process was not adequately discussed, which would presumably be handled by Farasis. The reviewer asked if there are any other partners needed for this portion.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that in the future work, the team will focus on delivering Gen1 Cell and the Gen 2 Development, which is logically planned according to the overall objectives of the project. For the Gen 1 cell, the project will target high capacity of specific energy of ~ 300 Wh/Kg, energy density of ~ 625Wh/L, a long cycle life of greater than 500 cycles, and safety, which are the key barriers and issues for current Li-ion batteries. However, the reviewer said that the investigators should describe their approaches as well as the composition and structure of both the cathode and anode in detail.

Reviewer 2:

The reviewer said that the team will deliver a Gen1 cell with 300 Wh/kg (625 Wh/L) of energy and greater than 500 cycle life this year. The team also proposed a plan to develop the Gen2 cell. From 330 Wh/kg to 360-375 Wh/kg, it seemed to the reviewer that the same C2 materials will be used while the anode will be changed from A1 to A2. The reviewer was unclear why the cell energy can be boosted to greater than 360 Wh/kg simply by changing the anode composite. The reviewer commented that if there is no further reduction on the porosity (of both electrodes) and other parasitic weight, it is not feasible to improve cell energy by only increasing anode capacity.

Reviewer 3:

The reviewer suggested adding calendar life testing, manufacturing scale-up, and electrode design parameters (i.e., areal capacity targets).

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that this project takes an important step of making commercially available materials work at stressful operating conditions to substantially increase cell gravimetric energy density to well over 300 Wh/kg. The technology has a high likelihood of commercialization and a strong intellectual property position. The reviewer said that it also places the domestic Li-ion battery supply chain in a much stronger position as compared to the international competition.

Reviewer 2:

The reviewer said yes, and elaborated that the on-going research will facilitate DOE’s goal to improve the energy density, power density, and cyclic performance.

Reviewer 3:

The reviewer remarked that this project is to develop an EV cell technology capable of providing 350 Wh/kg for 1,000 cycles at a cost target of $0.10/Wh. The reviewer found that this goal is well-aligned with DOE/EERE/VTO objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the resources for the synthesis and characterization for experiments are sufficient for the project.

Reviewer 2:

The reviewer said that this project is a large effort, and a $5.9 million award (with 50% cost-share) is in line with all of the materials screening, electrode optimization, cell optimization, and process scale-up R&D that will need to be done. However, this reviewer questioned if all the milestones and metrics can be completed by September 2019.

Reviewer 3:

The reviewer commented that the PI has subcontractors with two different national laboratories which both have sufficient resources to conduct the proposed work from materials research to pouch cell preparation. The team also has many industry partners to aid the R&D.

Presentation Number: bat356
Presentation Title: Lithium-Ion Cell Manufacturing Using Directly Recycled Active Materials
Principal Investigator: Mike Slater (Farasis Energy)

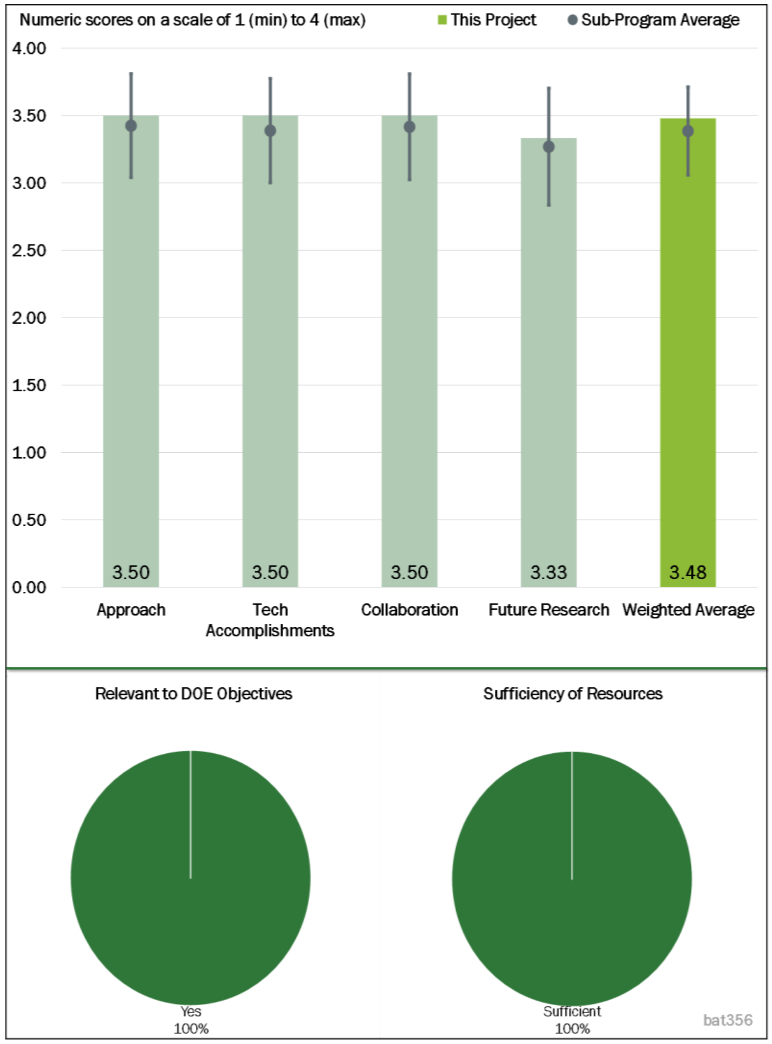

Figure 2-57 - Presentation Number: bat356 Presentation Title: Lithium-Ion Cell Manufacturing Using Directly Recycled Active Materials Principal Investigator: Mike Slater (Farasis Energy)

Presenter

Mike Slater, Farasis Energy

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that a direct recycling method is used to obtain recycled materials from discharged cells. The physical separation process is used for low-cost value recovery of wastes from the used batteries. The reviewer pointed out that an intermediate cell has been built with recycled active materials, which provides the data for quantitative technology valuation. The reviewer found that the project is well designed and feasible.

Reviewer 2:

The reviewer said that this project is well-designed and addresses all outlined technical barriers. The reviewer said that more emphasis should be placed on recycling of long-term tested cells (rather than the assumption made that 10-year old active materials perform the same as recycled ones), although the proposed direct recycling pathway for non-formed cells seems applicable to all cases. The reviewer remarked that the all-physical separation process is particularly interesting and elegant, but adding in the thermal treatment step to the process flow diagram would be helpful.

Reviewer 3:

The reviewer said that direct recycling of cathode and anode materials from spent Li-ion batteries is proposed with some preliminary results demonstrated. Physical separation processes are used to recover active materials while chemical purification and re-lithiation are proposed to be performed under mild conditions. The reviewer's main concern of the proposed approach is to ensure the fully restored Li inventory in each different NMC resource. Residual Li in NMC could vary significantly from each different recycled battery. The reviewer suggested that a method to predetermine Li inventory in the cathode is needed. The reviewer was not clear how to "regenerate" the cathode by adding more Li into the lattice structure. The majority of the proposed approach is based on the assumption that the pouch cells have already been successfully built by using the recycled materials.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that facility modifications were completed last year, capable of recycling active materials several kilograms per day. The project investigated thermal treatment of both the positive electrodes and negative electrodes. The reviewer pointed out that results show increasing the processing temperature increased the purity of recovered metal oxide but diminished the recovery of Gr. The project created and extended a process model for direct recycling, which helps optimize the recovery processes. The reviewer found that the progress is on track to realize the overall objective.

Reviewer 2:

To the reviewer, it seemed as though several of the key milestones are delayed and many have not yet been met, but the project is designated as 66% complete. The reviewer found that overall, good technical progress has been made, especially the cathode post-thermal-treatment capacity and Raman spectroscopy results. This reviewer is curious if the PI has considered the tradeoffs between anode thermal treatment temperature effects on Gr oxidation and removing SEI components. The requirements of Gr yield and SEI layer removal seem to be in competition with each other.

Reviewer 3:

The reviewer said that the project has studied the thermal treatment effects on cathode and anode recycling, and demonstrated the materials separation. However, there are quite a few important milestones delayed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer pointed out that the company teams up with LBNL by using their characterization facilities.

Reviewer 2:

The reviewer noted that more collaborators than just LBNL will likely be needed for the extensive materials characterization that will be required to address the material complexity issues the PI identified.

Reviewer 3:

The reviewer said that this project is performed through the collaboration with LBNL. The collaboration helps chemical diagnostics and materials characterization to guide recycling process development.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer found that the future work is well-planned. The team will extend a direct recycling process to additional formed cells and complete modules feedstocks; complete cell construction, and gain understanding of the impact of recycled materials on technology lifetime.

Reviewer 2:

The reviewer recommended that the challenges and barriers slide needs to be expanded for more granularity. The proposed future research addresses the major open challenges with the exception of retesting long-term-cycled recycled active materials (although it is at least addressed in the assumptions section). The reviewer said that it would be interesting to see, for example, how active materials perform that are tested for 1,000 USABC cycles, which are then recycled and retested for another 1,000 cycles. This reviewer recognized the length of time involved with that plan, and it may be beyond the scope of the given timeframe. The reviewer pointed out that it will be difficult to finish this project by January 2019, and an extension may be needed.

Reviewer 3:

The reviewer said that proposed future research will extend the direct recycling process to form cells and complete modules. Without successful delivering the cells consisting of recycled materials, it is too early to extend the process to modules and other cell chemistries. The reviewer said that the team needs to identify the key fundamental challenges of direct recycling process and address them first before rushing into building cells or modules. The reviewer said that a clearer techno-economic model is needed to understand the cost for the proposed recycling process and its impact.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said yes, and elaborated that implementation of this project will lower the costs for battery production and reduce the environment pollution of the disposed batteries.

Reviewer 2:

The reviewer said that direct recycling of active materials from spent batteries are relevant to DOE/VTO objectives.

Reviewer 3:

The reviewer said that recycling cathode active materials is critical to meeting VTO’s new low/no Co goals. Recycling anode and cathode active materials should significantly reduce cost, as the recycling costs will be less than the synthesis cost of pristine materials. The reviewer found that this project will help in achieving VTO’s ultimate cost target of $80-$100/kWh.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the facilities and characterization for experiments are sufficient to achieve the goal of the project.

Reviewer 2:

The reviewer said that Farasis has the ability to build cells while LBNL has resources for characterization and materials testing.

Reviewer 3:

The reviewer said that $1.8 million for this project is reasonable, but it would be interesting to know how much has been spent to date relative to the milestone progress.

Presentation Number: bat357
Presentation Title: Thicker Cathode Coatings for Lithium-Ion Electric Vehicle Batteries
Principal Investigator: Stuart Hellring (PPG Industries)

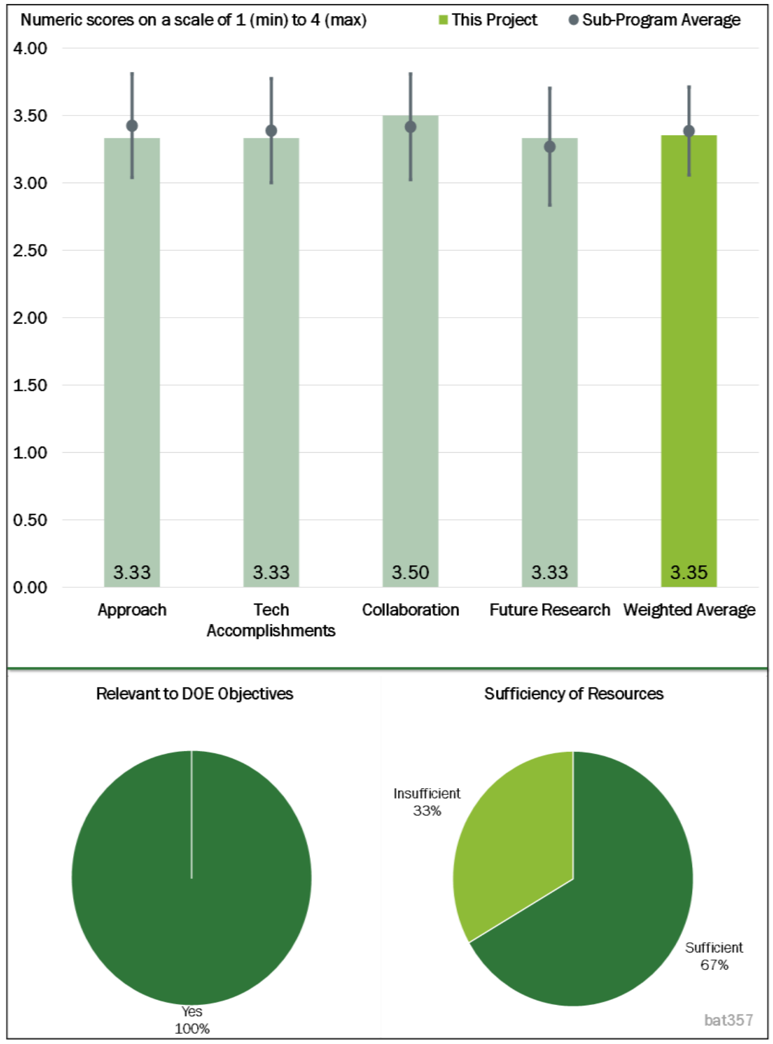

Figure 2-58 - Presentation Number: bat357 Presentation Title: Thicker Cathode Coatings for Lithium-Ion Electric Vehicle Batteries Principal Investigator: Stuart Hellring (PPG Industries)

Presenter

Stuart Hellring, PPG Industries

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that this project is highly relevant and feasible, as thick coatings for lower cost and higher energy density are important. However, there is no plan in this work on how to address the high-power limitations of these coatings (i.e., 5-9 mAh/cm^2). The reviewer also commented that no details were provided on how to switch from the solvent system (which is of limited benefit over conventional NMP to a pure water system.

Reviewer 2:

The reviewer commented that the project is to address the critical barrier of a low-area density electrode, which limits the overall energy density. The project is designed to investigate the NMP-free cathode. This approach will increase the environmental compatibility of the cathode manufacturing. The reviewer said that the thick film performance will be improved by optimizing processing conditions, and battery size/weight/cost will be investigated. The PPG binder has some advantages over the NMP binder. However, the reviewer was unclear why the PPG binder is better than the NMP binder. The composition and the properties of the PPG binder are unclear. It is unclear why the PPG binder-based cathode can be thick without sacrificing the power density and cyclic performance. In other words, the reviewer thought that the reason for enabling thick cathodes should be described clearly and justified.

Reviewer 3:

The reviewer said that this project develops an NMP-free solvent to make thick cathodes with good flexibility without sacrificing the electrochemical properties. High areal capacity is beneficial to improve cell energy. However, increasing cathode loading/areal capacity without further reducing the electrode porosity will have limited impacts on the energy increase. The reviewer recommended that the project needs to calculate the cell-level energies that the team would like to reach by using different thicknesses of electrodes instead of simply increasing the cathode loading. Electrolyte intake will also increase proportionally if the cathode becomes thicker lowering the cell-level energy. The reviewer said that the percentage of NMC in the electrode needs to be increased to 96% or above to further increase the areal capacity. The reviewer asked if the minimum amount of PPG binder is 4%, or it can be further lowered.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted the project achieved a greater than 5.3 mAh/cm^2 areal capacity and passed mandrel test with good quality. Thick electrodes are tested in pouch and cylindrical cells with some discrepancy though. The reviewer said that final goals have been reached, and the team will develop a matching anode to build cells.

Reviewer 2:

The reviewer observed excellent progress on the processability of the thick cathodes, but much work on the anode and rate performance metrics still needs to be done. It seems as though the team is having trouble with continuity of full cell builds as well.

Reviewer 3:

The reviewer said that the PPG binder has been used to manufacture a high area-density cathode, reached up to 145 um per side for the double-sided coating with pilot-scale R2R coater, up to 40 mg/cm^2 mass loading. The reviewer said that the cathode coatings exhibited good flexibility and peel strength (90°), exceeding 66N/m to meet final target specification. However, the reviewer thought the use of "NMP-free binder" is confusing. In fact, it is not a binder-free cathode. Instead, the PPG binder is used to replace the NMP binder

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said great collaboration throughout the whole team, including industry, a national laboratory, and universities.

Reviewer 2:

The reviewer said that this project is performed through collaboration with LG Chem Power, Idaho National Laboratory (INL), and PSU.

Reviewer 3:

The reviewer inquired why there are so many partners for full cell testing. It seemed as though PPG could benefit from spreading the activities better throughout the team.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer detailed that future research is to develop a high-capacity electrode with a thicker coating, and further optimize electrode pairs toward final deliverables. Also, the team will apply and optimize the PPG binder for high Ni active materials. The team is also planning water stable active materials.

Reviewer 2:

The reviewer pointed out that the team has already accomplished the final target. The team is trying to develop a thick anode to match the cathode. In addition to the work the team proposed, other modifications are also needed. The reviewer detailed that the percentage of NMC is 93%, which is less than what industry cells usually use, i.e., 96% or higher. The reviewer asked if there is a reason that the PPG binder needs to be 4% in the electrode fabrication. Porosity control is more challenging in thick electrode but more meaningful for improving cell-level energy than just making thicker electrodes. The reviewer said that the team needs to consider how to control the porosity and tortuosity of the thick electrodes in order to reach the same good electrochemical performances in thicker but denser electrodes.

Reviewer 3:

The reviewer said that the proposed future research is weighted too heavily on the processability of the thick electrodes. The reviewer commented there is not enough emphasis on performance limitations that these types of electrodes must overcome at high discharge rates. The processability and performance need to be approached holistically. Also, the reviewer pointed out that there are not enough details on how the pure water stability of the cathode materials will be characterized and addressed.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer commented that the thick electrode with high areal capacity will boost the cell-level energy, and is directly relevant to DOE/VTO objectives in developing high-energy EV batteries.

Reviewer 2:

The reviewer said yes. If successful, the outcome of the project will reduce the overall battery cost and size/weight, and improve safety during the manufacturing process.

Reviewer 3:

The reviewer said that the thick electrode coatings are highly applicable to achieving the ultimate VTO cost target of $80-$100/kWh, and the ultimate gravimetric energy density target of 500 Wh/kg.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that in order to address what this reviewer considered as the process-property-performance gap in this project, it is underfunded.

Reviewer 2:

The reviewer said that the resources are sufficient to achieve the goal of project.

Reviewer 3:

The reviewer said that the University of Michigan has the pouch cell facility, LG Chem also participates in the pouch cell preparation and testing, Penn State is working on matching anode, while Coulometrics works on cathode coating. The reviewer said that the role of INL seems to be overlapping with other team members.

Presentation Number: bat358 Presentation Title: Advanced Separators for Vehicle Lithium Battery Applications Principal Investigator: Junqing Ma (Celgard)

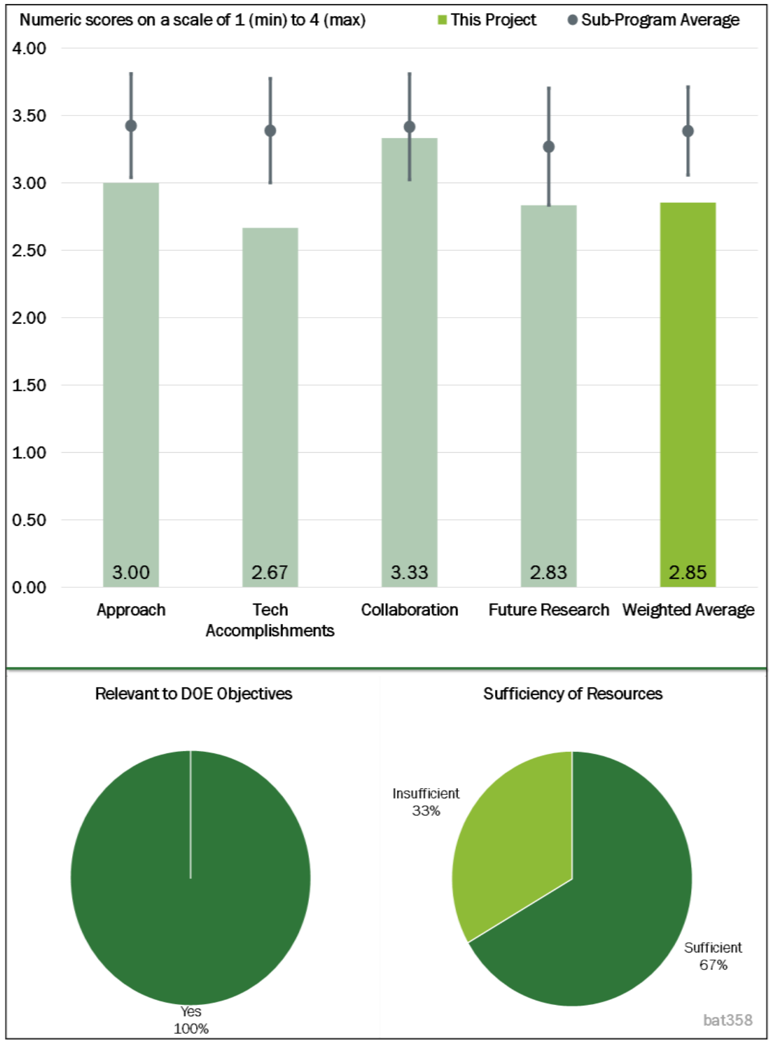

Figure 2-59 - Presentation Number: bat358 Presentation Title: Advanced Separators for Vehicle Lithium Battery Applications Principal Investigator: Junqing Ma (Celgard)

Presenter

Junqing Ma, Celgard

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the approach is feasible and addresses relevant technical barriers, but this reviewer does not believe the project addresses the main challenges associated with 5V systems. The reviewer noted that the electrolyte and the cathode surface stability are far more critical to overcoming this barrier. It seems as though the project considers these aspects, but the lead is a separator developer.

Reviewer 2:

The reviewer detailed that the project aims to develop a separator with high voltage stability in 5V cells, and a nanometer-scale ceramic coating on the separator to enhance the resistance to electrochemical oxidation. After the conformal ceramic is coated and the polymer composite separator is produced, the 5V cells will be used to test the cycling and stability of the separator. However, the rationale for the separator design is not described. The reviewer elaborated that the chemical composition, chemical structure, and microstructure are unclear. The specifications and properties of separator are also unclear, and the method for separator evaluation is not described. The reviewer said that the advantages of the proposed separator over the current separators need to be described.

Reviewer 3:

The reviewer detailed that Celgard will fabricate protected separators that can tolerate 5V for high-energy batteries. The separators will be tested in the pouch cell provided by Farasis. However, the reviewer did not know what kind of coating materials or method will be used to enable the high-voltage operation stability of separators. The reviewer said that fundamental knowledge and a roadmap are lacking in this project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the project is over a year old and only one Technical Accomplishments slide was given with no data. The first major milestone was at least met by providing five ceramic coated separators to Farasis.

Reviewer 2:

The reviewer summarized that five ceramic coated separators and several polymeric composite separators have been fabricated and characterized. The first-generation 5V cells showed encouraging capacity and cycling performance. The reviewer pointed out that the team identified issues for capacity fading including cathode dissolution and electrolyte degradation. However, the chemical composition, chemical structure, and microstructure need to be described, and details on the capacity and cycling testing need to be provided. The reviewer recommended that targeted performance metrics should also be provided.

Reviewer 3:

The reviewer pointed out that there is only one page summarizing the accomplishments to date, although the project started more than one year ago. The reviewer reported Celgard fabricated and five ceramic coated separators were characterized, to which this reviewer asked what they are; what the characterization results are; and how they are expected to differ from other coatings and tolerate high voltage. No figures or experimental results are provided, which made the review process hard for this reviewer. Further, this reviewer dropped by three times during the poster session, but no one was there answering questions.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that this project is performed through the collaboration with Farasis Energy and ANL.

Reviewer 2:

The reviewer noted that a lean, but strong team has been assembled in Farasis, ANL, and Celgard. The reviewer clarified that Farasis is a reliable partner for the full cell testing, and ANL will handle the cathode powder coatings for achieving a cell voltage of 5V.

Reviewer 3:

The reviewer detailed that Celgard teams up with Farasis Energy and ANL. Farasis will provide 5V cell design and evaluate 5V cell cycling performances and fabricate cells.

The reviewer said that ANL will do coating work to enhance the cathode stability at high voltages. The reviewer said that no results were provided from the partners in the slides.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that Celgard will work with Farasis and ANL on down-selecting fabricated separators and developing protected cathode materials to address the issues identified in earlier 5V cells fabricated by Farasis. The reviewer detailed that future research also includes the evaluation of the stabilized 5V cells based on cycling and storage stability and finalizing the design for 12-month deliverable cells.

Reviewer 2:

The reviewer found that the plan to meet the goals of fabricating a separator that can operate at 5V is not clear. The reviewer said that simply down-selecting from the fabricated separators is not a good plan; what if none of them work. Without a fundamental understanding and a clear strategy to address the challenges, it is not promising that the project will meet the final goals.

Reviewer 3:

The reviewer detailed that the most important aspects of 5V systems (electrolyte and cathode surface stability) were identified as both remaining challenges and needed future work, but it is not clear to this reviewer what role Celgard will play in overcoming those barriers. Therefore, the project, may need to be re-scoped for the remaining 2 years.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said yes, 5V systems are an important mark to hit for achieving VTO's ultimate gravimetric energy density target of 500 Wh/kg. The reviewer is of the opinion that this project is not working on the most important aspects to achieving 5V, however.

Reviewer 2:

The reviewer said that the slides/report should describe the reliance of project.

Reviewer 3:

The reviewer said that improving separator stability at high voltages is relevant to VTO needs. This reviewer was not quite sure why there is a need for high voltage at 5V though.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that $2.5 million over 3 years is adequate for this project and meeting the key remaining milestones.

Reviewer 2:

The reviewer said that the resources are sufficient to achieve the project goal.

Reviewer 3:

The reviewer commented that the PI mentioned in the "Remaining Challenges and Barrier" slide that "Full evaluation/understanding of separators degradation requires extended time and resources." Although the reviewer believed a national laboratory should have most of the required resources to conduct the fundamental research, the team seems to think their current resources are insufficient.

Presentation Number: bat359
Presentation Title: Status and Challenges of Electrode Materials for High Energy Cells
Principal Investigator: Stanley Whittingham (Binghamton University)

Presenter

Stanley Whittingham, Binghamton University

Reviewer Sample Size

A total of five reviewers evaluated this project.

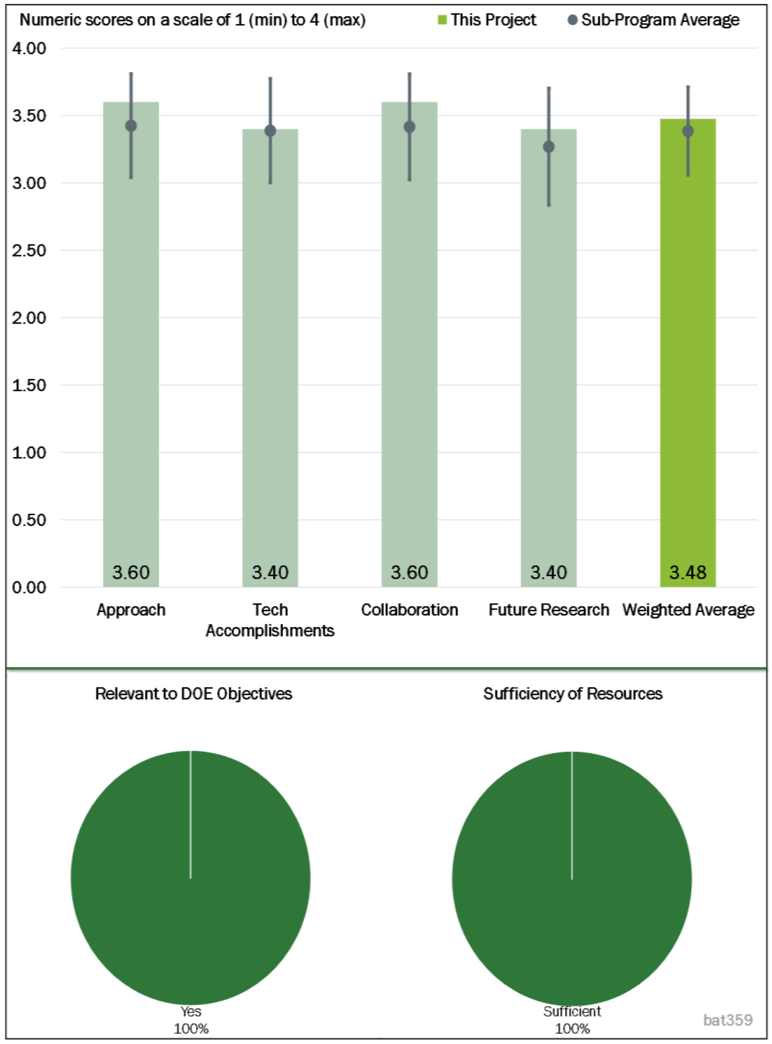

Figure 2-60 - Presentation Number: bat359 Presentation Title: Status and Challenges of Electrode Materials for High Energy Cells Principal Investigator: Stanley Whittingham (Binghamton University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the key barrier to achieve the Battery 500 objective is directly addressed in this project by focusing on the main bottleneck, i.e., the cathode. The approach rightfully calls for a dual-pronged development path—further enhance currently used and already mature layered cathodes and also develop the less-mature but potentially more energetic and less costly sulfur cathode. The reviewer said that the workplan is well-thought out and implementable.

Reviewer 2:

The reviewer commented that the problems of high-Ni NMC have been clearly defined, and they are being addressed. The team is starting with commercial material for baselines, which is the correct approach. The team will be looking carefully at optimizing structure/morphology.

Reviewer 3:

The reviewer said that the project is well-designed and feasible. The challenges of NMC and NCA are well addressed, and the pathway forward is presented well.

Reviewer 4:

The reviewer detailed that the goal of the overall Battery 500 project is to achieve a cell level specific energy of 500 Wh/kg through using a high-capacity cathode consisting of Ni-rich NMC or sulfur cathode, Li anode, and compatible electrolyte. The objective of this project is to evaluate cathode materials with different compositions in terms of rate capability and cycle life at different loadings, and make a recommendation to the project on future cathode compositions. The reviewer said that commercial NMC materials of compositions 622 (baseline) and 811 obtained different sources were evaluated in comparison with the NCA cathode and with materials synthesized by the Battery 500 PIs. There are several aspects still unknown with these Ni-rich materials including the role of Al in NCA, the effect of cathode loadings and coatings, and their degradation mechanisms, which are addressed in this project. The reviewer said that this project is well-designed and integrated with the other efforts under Battery 500.

The reviewer commented that with multiple teams working on the same materials, there is some confusion (and may be duplication as well) on who is doing what. Each of these groups (Binghamton University [BU], University of Texas-Austin [UT-Austin] and University of California-San Diego [UCSD]) have end-to-end capability to design synthesize, characterize and evaluate the new cathode materials, which made this reviewer wonder why there is this overlap.

Reviewer 5:

The reviewer was unclear why efforts were devoted to studying NCAs because the Battery 500 already committed to a Ni-rich NMC or S as the positive electrode and Li-metal as the negative electrode. Furthermore, the reviewer was unclear how the knowledge gained from studying NCAs can help solve much of the challenges facing NMCs because the two materials have different physical and chemical properties and degradation behavior.

The reviewer was unclear why the 622 and 811 NMCs obtained from the South Korea supplier were considered as baseline materials because their performance and durability appear to be worse than the commercial NMC811 by TODA America (see BAT164 presentation). The reviewer said that it may be helpful to exchange information with project teams outside the Battery 500 to select a baseline material.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that at the current stage, most of the work in the project is to characterize the baseline materials, which is presented well.

Reviewer 2:

The reviewer observed a significant amount of technical progress in the project. A number of studies involving baseline cathode materials, studies related to the role of Al in the stability of NCA, and air and thermal stability, among others, have been carried out prior to downselecting to the 811 cathode, which this reviewer described as a good selection.

The reviewer did have several comments, though. The authors have made general comments on air stability of several cathodes. As is well-known, this reviewer noted that property can also be tailored using a suitable coating. Additionally, making a statement on the cyclability of a certain material (in this case NCA, Slide 13) based on room temperature cycling up to 100 times can be misleading for material selection unless the difference in performance is quite significant, which it was not in this case. The reviewer opined that this begs the question of why one cannot cycle the cells at a higher temperature to accelerate degradation for easier materials differentiation.

Reviewer 3:

The reviewer observed an excellent job on characterizing commercial material. Studies of Li range in 622 and 811 are good, as are studies of Al. Many of the characterization measurements are not new, however. Of course, the project is still at an early stage. However, the reviewer expressed concern that the rate of progress is modest so far.

Reviewer 4:

The reviewer said that good progress has been made in characterizing and understanding the baseline NMC-622 material, which has been demonstrated in pouch cells (at PNNL), and in evaluating NMC-811 and NMC-900505 materials in comparison with the traditional NCA cathode. Compared to the baseline 622 cathode, 811 cathode gives higher capacity and better cycle life even at higher cathode loading and is of low cost and hence has been recommended for Battery 500 project. The reviewer said that when compared to the NCA cathode, which is well-studied and is routinely used in industry, the NMC 822 cathode has better air stability, less gassing, and high thermal stability. The role of Al is intriguing and seems to distribute uniformly in the bulk forming a solid solution and improving the cycle life.

The reviewer referenced prior comments, and noted that it is difficult to identify which group is doing what in this Battery 500 project, especially the manner in which the results are presented. There are some benefits in having good coordination in establishing future cathode materials for Battery 500, but with this much of overlap, there may be duplication and redundancy. The reviewer also pointed out that if these materials (622, 811) are already being commercially produced, the reviewer wondered what the rationale is, for DOE projects trying to synthesize/characterize these formulations. The reviewer said that instead, projects should focus other (new) formulations and with new coatings.

Reviewer 5:

The reviewer remarked that many of the learnings and recommendations are well-known in the literature, such as NMC 811 has higher capacity and higher power capacity. However, the reviewer asked if the manufacturing cost/kWh of NMC811 is lower than 622. Please carry out and report cost estimates.

The reviewer pointed out that the PDF presentation did not provide any evidence to support the statement that "Extended cycling leads to cracking of particles" (Slide 14). Also, the reviewer said that there is no evidence for keeping "lattice expansion to a minimum" to solve the cracking problem because a large strain does not necessarily lead to a large stress; e.g., many low modulus materials have low stress even at high strain.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the collaboration among team members is outstanding.

Reviewer 2:

The reviewer said that the project has excellent collaboration among the team members.

Reviewer 3:

The reviewer observed good collaboration activities with the PIs in the Battery 500 projects, with researchers from PNNL, UCSD and UT-Austin, and also other DOE national laboratories. The reviewer suggested more active collaboration with industrial partners (e.g., TODA, Umicore, BASF, etc.).

Reviewer 4:

The reviewer remarked that the collaboration within the Battery 500 team seems strong. However, the team may benefit from collaborations with other DOE funded project teams, especially because many have or are working on Ni-rich NMCs.

Reviewer 5:

The reviewer recommended that an industrial partner—beyond "dissemination of data"—would be desirable.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the directions of future research are appropriate, and time will tell if any of the directions will be fruitful.

Reviewer 2:

The reviewer commented that the future direction seems to be lithium nickel manganese cobalt aluminum oxide (NMCA), which is reasonable. It will be interesting to see the progress in the later years, especially how to achieve both thermal stability and high energy density.

Reviewer 3:

The reviewer noted that there are several outstanding issues with these cathode materials, i.e., poor thermal stability, increased metal dissolution and capacity fade, and higher reactivity towards electrolytes with the Ni-rich formulations. In addition to the providing higher specific capacity, these cathodes need to function well at higher loadings. The reviewer said that, appropriately, the future studies will address these issues, and these studies are consistent with DOE goals of high specific energy, low-cost, and safe Li-ion batteries.

Reviewer 4:

The reviewer said that the proposed future research aimed at energy and durability improvement is quite comprehensive and if successfully completed will contribute significantly to the Battery 500 goals. The reviewer recommended showing the Wh/l values of the cells so that reviewers can have an appreciation of the cell system in question.

Reviewer 5:

The reviewer said that as was discussed during the review meeting, there may be a different set of challenges as the team moves from 300 Wh/kg to the final goal of 500 Wh/kg using Ni-rich NMCs/Li-metal. The reviewer recommended that it would be helpful to identify what these challenges are early in the project (not just the challenges encountered in achieving 300 Wh/kg) to guide the project. The reviewer was unclear from the presentation whether the team has multiple approaches and options to tackle the problems identified: minimizing cracking and mechanical degradation, and improving ionic and electronic conductivities.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer pointed out that a higher capacity cathode is a key requirement for developing a cost-effective, safe and high-energy battery to support DOE's overall goal. This project is thus extremely relevant.

Reviewer 2:

The reviewer said that for a widespread use of EVs, the batteries need to be lightweight, compact, safe, and of low-cost. The state-of-the-art Li-ion batteries are inadequate to fulfil these needs. Higher energy density and lower cost cathode materials are required to improve the specific energy for Li-ion cells and reduce overall cost for the battery. The reviewer said that state-of-the-art cathode materials provide capacities of only ~170 mAh/g, which needs to be increased to greater than 220 mAh/g to achieve the cell level energy of 500 Wh/kg. Battery researchers need to develop new Ni-rich cathode materials, which the present project is duly addressing.

Reviewer 3:

The reviewer said yes, and clarified that a high-energy density cathode is one of the key issues to achieve overall energy density of the battery.

Reviewer 4:

The reviewer said that the project supports the overall DOE Battery 500 objectives.

Reviewer 5:

The reviewer observed good relevance.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the team has sufficient resources for the project with one possible exception in the area of measuring and understanding mechanical behavior and degradation of Ni-rich NMC electrodes.

Reviewer 2:

The reviewer found that the total funds should be sufficient for the project team members to complete the tasks on schedule.

Reviewer 3:

The reviewer said that resources are okay.

Reviewer 4:

The reviewer said that resources are sufficient to carry the work.

Reviewer 5:

The reviewer said that the resources are adequate for the scope of the project, though the reviewer was not clear what the specific budget for BU is (and individual organizations in the Battery 500).

Presentation Number: bat360
Presentation Title: Overview and Synthesis of High-Nickel Nickel Manganese Cobalt Oxide (NMC) Cathodes
Principal Investigator: Arumugam Manthiram (University of Texas-Austin)

Presenter

Arumugam Manthiram, University of Texas-Austin

Reviewer Sample Size

A total of five reviewers evaluated this project.

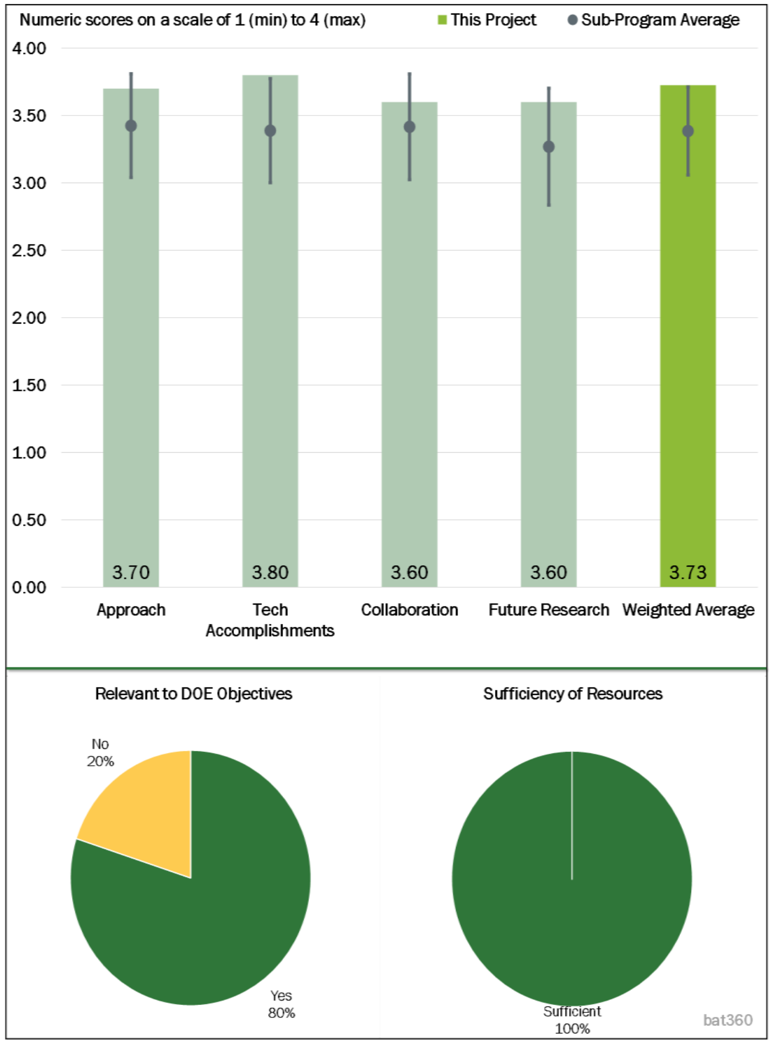

Figure 2-61 - Presentation Number: bat360 Presentation Title: Overview and Synthesis of High-Nickel Nickel Manganese Cobalt Oxide (NMC) Cathodes Principal Investigator: Arumugam Manthiram (University of Texas-Austin)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the key barrier to achieving the Battery 500 objective is directly addressed in this project by focusing on the main bottleneck, i.e., the cathode. The team is directing its efforts to further enhancing the properties of currently used and already mature layered cathodes in order to increase the capacity without comprising durability, safety, and cost. The reviewer remarked that the project is highly focused with a well-organized research plan.

Reviewer 2:

The reviewer observed clearly stated objectives and stressed that discussion of how the team will try to reach them was also included.

Reviewer 3:

The reviewer said that the project approach, i.e., small percentage elemental doping to address the stability issue, is good.

Reviewer 4:

The reviewer asked what the goal of scaling up synthesis for the project is. The target of 500 g or 1,500 g per batch seems quite arbitrary, especially because it appears to be all based on trial-and-error instead of a process model.

Reviewer 5:

The reviewer said that the project is well-designed and feasible. The reviewer commented that although the secondly particle size is well-controlled and uniform for all nickel cobalt manganese oxide (NCM), the PI may want to investigate the correlation between Ni content and the morphology of the primary particle. The reviewer said that the primary particle will influence the electrochemical performance, degradation, and air stability.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said that high-Ni NMC characterizations are underway, which is good. Using Al doping to suppress air-sensitivity and improve cyclability has been shown, which the reviewer characterized as really impressive for this early in the project. The reviewer said that scale-up is excellent, with great early results.

Reviewer 2:
The reviewer said that within a short time, less than 2 years, the technical accomplishment is excellent.

Reviewer 3:
The reviewer said that the PI focused on the major technical barriers and made significant progress.

Reviewer 4:
The reviewer remarked that the project has made significant progress towards understanding the structure-stability-capacity relationships of the layered cathodes with a view to improving their capacity. The team was able to produce both 811 and 900505 cathode materials in large batches that demonstrated better performance than commercial materials (622 and 811). (The reviewer cautioned that not all commercial samples represent the state of the-art and hence drawing absolute conclusions can be risky unless well-known suppliers are benchmarked). The reviewer said that work related to air-sensitivity is quite comprehensive. The authors carried out an insightful work on the effect of Al-doping in 9406 material that showed how it reduces lattice strain. The reviewer pointed out that most of the slides are also very self-contained with a nice take-home message at the end of the slides.

Reviewer 5:
The reviewer said that air and moisture sensitivity and stability of the NMCs should be quantitatively defined. The reviewer noted that the commercial NMC811 by TODA America (see the BAT164 presentation) seems to be stable in water, and asked why. The reviewer asked what mechanisms are responsible for the secondary particle pulverization. The team should collaborate with people who can measure the mechanical properties and fracture strength of particles.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said that the project has excellent collaboration among the team-members.

Reviewer 2:
The reviewer pointed out that the PI actively collaborates with other teams within Battery 500.

Reviewer 3:
The reviewer said that the collaboration among team members is excellent.

Reviewer 4:
The reviewer remarked that the collaboration within the Battery 500 team seems strong. However, the team may benefit from collaborations with other DOE funded project teams, especially because many have or are working on Ni-rich NMCs.

Reviewer 5:

The reviewer said that the project would benefit from industrial collaboration

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer found that future directions are very well-defined, much better than in most other projects; and in the right directions.

Reviewer 2:

The reviewer remarked that the future work, i.e., optimizing cathode synthesis, and surface/bulk stabilization, are important to achieve high energy density and stability oxide cathodes.

Reviewer 3:

The reviewer said that the proposed future research goals emphasizing higher capacity, durability, and safety are critical. Although not explicitly highlighted, the reviewer expressed certainty that the team will be focusing on reducing the Co content to as low as possible in order to lower cost.

Reviewer 4:

The reviewer remarked that as was discussed during the review meeting, there may be a different set of challenges as the team move from 300 Wh/kg to the final goal of 500 Wh/kg using Ni-rich NMCs/Li-metal. The reviewer thought that it would be helpful to identify what these challenges are early in the project (not just the challenges encountered in achieving 300 Wh/kg) to guide the project.

Reviewer 5:

The reviewer said that the PI plans to explore the long-term cyclability of NMC811 with various charge voltage cutoffs (4.2V-4.5V). If charging Ni-rich to higher voltage beyond 4.4V, the PI should have a thorough energy density/cycling stability comparison of Ni-rich oxides with high Mn or high-Co NCM.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said yes, and elaborated that the PI is trying to achieve Battery 500 objectives.

Reviewer 2:

The reviewer remarked that a high energy density oxide cathode is one of two approaches to achieve the overall goal of the Battery 500 program.

Reviewer 3:

The reviewer said that development of a high-capacity cathode that meets other battery requirements such as safety, durability, and cost will support DOE’s objective of a high-energy density battery.

Reviewer 4:

The reviewer said that the project supports the overall DOE Battery 500 objectives.

Reviewer 5:

The reviewer said high energy density.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked that the team has sufficient resources for the project, with one possible exception in the area of measuring and understanding mechanical behavior and degradation of Ni-rich NMC electrodes.

Reviewer 2:
The reviewer said that the resources are sufficient to achieve the stated milestones in a timely fashion.

Reviewer 3:
The reviewer said that the resources should be sufficient to achieve the milestones of the project on schedule.

Reviewer 4:
The reviewer said that resources are okay.

Reviewer 5:
The reviewer indicated that resources are sufficient to carry out the work.

Presentation Number: bat361
Presentation Title: Lithium-Sulfur Batteries: From Materials Understanding to Device Integration
Principal Investigator: Yi Cui (Stanford University)

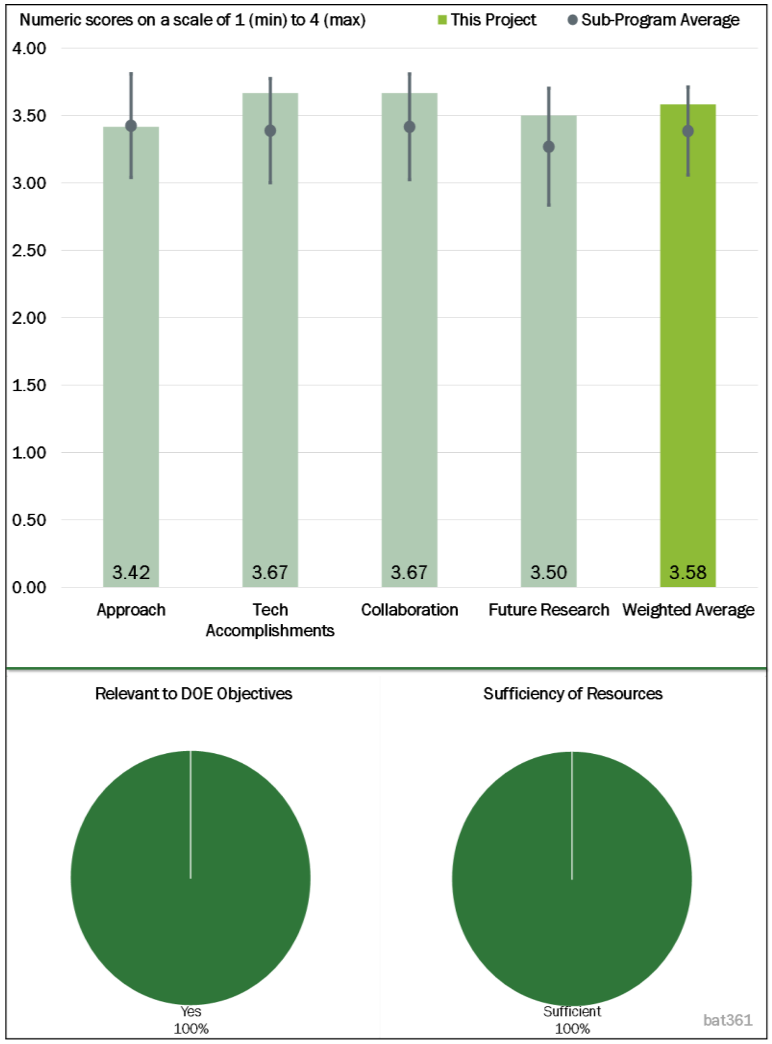

Figure 2-62 - Presentation Number: bat361 Presentation Title: Lithium-Sulfur Batteries: From Materials Understanding to Device Integration Principal Investigator: Yi Cui (Stanford University)

Presenter

Yi Cui, Stanford University

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the Stanford/PNNL team has done excellent in developing high-energy Li-S batteries (high capacity and stability with long cycle life) through materials understanding and selection and device Integration, with the goal of achieving 500 Wh/kg specific energy to power EVs at low cost. The team has completed the baseline properties of the Li-S cathode required to reach 300 Wh/kg based on Battery 500 cell design. Developing polymer membranes and Li-metal protection methods is of great interest. The reviewer found that the project has made remarkable progresses in addressing the technical barriers.

Reviewer 2:

The reviewer said that the approach taken by the team that leverages its expertise in nanomaterial design and synthesis combined with novel assembly and simulations to develop the Li-S battery clearly addresses the key technical barriers to achieve the objectives of the Battery 500 program.

Reviewer 3:

The reviewer remarked that the S nanostructure and Li-metal anode modification approaches are well designed and feasible. The S catalyst works, is new, and needs more research attention.

Reviewer 4:

The reviewer said that energy/volume, in addition to energy/mass, should be considered if the Li-S research is aimed at automotive applications.

Reviewer 5:
The reviewer observed that the presentation identified many approaches. The reviewer expressed confusion about which one or few is/are specifically with this project.

Reviewer 6:
The reviewer pointed out there was no mention of volumetric energy density, which is of primary importance for vehicles.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented brilliant and extremely innovative work on addressing S battery limitations. The reviewer was especially impressed with the very novel work on enabling Li-metal

Reviewer 2:
The reviewer said that the team has demonstrated several significant technical accomplishments and progress towards the overall project. The project is in good shape in terms of milestones.

Reviewer 3:
The reviewer found that lots of excellent progress has been demonstrated.

Reviewer 4:
The reviewer said that it is very helpful to standardize Testing Requirements and Protocols for Li-S cells.

Reviewer 5:
The reviewer commented that thanks to a multitude of innovative concepts and studies, the team has achieved a number of significant results that demonstrate measurable progress towards the program goals. This is evidenced, among others, by the number of publications in high-quality journals. The reviewer said that the team deserves kudos for their novel work. Despite this progress, the fundamental issues both at the Li as well as the S electrodes remain. The reviewer was unclear how these approaches affect the energy density of the cell (Wh/l) because the reviewer did not find in the presentation the actual composition of the S electrode. It will be useful to report this metric in future presentations for ease of understanding. The reviewer said that among the Li hosts, SiO and aluminum fluoride (AlF_3) look interesting but again it is unclear how the Wh/l values get affected by the hosts and how to tailor the amount of Li desired.

Reviewer 6:
The reviewer said that the statement in one of the slides under Accomplishment, “Pouch cell: Multilayer stacking/pressing and lean electrolyte brings more challenges than in Li/NMC cells,” does not convey much information. The reviewer inquired what the challenges are, and how the team is going to solve these challenges.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said that the project has a strong collaboration across the team members. This is evidenced by the fascinating work involving cryogenic electron microscopy that allowed resolution down to individual Li atoms.

Reviewer 2:
The reviewer found that the collaboration within the Battery 500 team seems strong.

Reviewer 3:

The reviewer said that the team has been collaborating with faculty at Stanford University and the University of California-Los Angeles (UCLA). The collaboration is very productive.

Reviewer 4:

The reviewer pointed out that the PI actively collaborates with other teams within Battery 500.

Reviewer 5:

The reviewer said that the collaborations between this project and other team members are clearly demonstrated during the presentation.

Reviewer 6:

The reviewer recommended that the project would benefit from industrial participation.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that this project has the best chance of solving the Li-metal problems.

Reviewer 2:

The reviewer found that the proposed future work is well-planned. The team will focus on several key tasks, such as the interaction between S species and multifunctional binders, and select the optimal materials to re-capture the active S species diffused in the electrolyte. The reviewer detailed that the plan to test S cathodes with high areal mass loading at high current densities may lead to new findings. Developing 3-D Li-metal anodes and stable electrolytes holds a great promise.

Reviewer 3:

The reviewer described proposed future work as obvious and to-the-point—how to improve durability at an acceptably high cathode loading. This has been a formidable challenge for decades now and hopefully the novel approaches proposed might bring about significant improvement to the results. The reviewer referenced the use of solid electrolytes, and inquired if it is a part of the Battery 500 program.

Reviewer 4:

The reviewer noted that energy/volume should be a key consideration of a go/no-go decision if the Li-S research is to go forward for EV applications.

Reviewer 5:

The reviewer said that besides the proposed future research, the PI may want to improve the rate capability by understanding catalyst effect on S reaction kinetics.

Reviewer 6:

The reviewer found that many promising concepts and progress have been demonstrated. The reviewer said that it will be great if the future research can be a little bit more focused.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer commented that the development of a high-capacity S cathode and a stable Li anode is the key task of the Battery 500 program that directly supports the DOE objectives of a low-cost, high-energy density battery,

Reviewer 2:
The reviewer said that energy/volume should be key considerations of a go/no-go decision if the Li-S research is to go forward for EV applications.

Reviewer 3:
The reviewer stated that the team has been working on the design and fabrication of S cathodes with high capacity and stability with long cycle life, and Li-metal anodes with high capacity, high CE, and long cycle life, which is critical for commercialization of Li-S batteries and highly relevant to VTO program goals.

Reviewer 4:
The reviewer remarked that the alkali metal-S chemistry should always be one of the research focus areas towards high-energy density batteries. Further, this reviewer asserted that the project supports Battery 500 objectives.

Reviewer 5:
The reviewer said that the project clearly addresses one of two approaches (S and layered-oxide) in developing a high-energy cathode.

Reviewer 6:
The reviewer remarked high energy density.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that given the quality and quantity of results that come out of Professor Cui's lab, the resources seem insufficient and should be increased, unless his team is provided additional funding via other routes. The reviewer was unsure about interpreting the funding level listed on the presentation.

Reviewer 2:
The reviewer said that the team has sufficient resources for the project.

Reviewer 3:
The reviewer remarked that the team has fully used the resources at Stanford, PNNL, and UCLA through collaboration.

Reviewer 4:
The reviewer said that resources are sufficient.

Reviewer 5:
The reviewer remarked that resources for the project are sufficient to achieve the stated milestones in a timely fashion.

Reviewer 6:
The reviewer said resources are okay.

Presentation Number: bat362
Presentation Title: Lithium-Metal Anodes: Problems and Multiple Solutions Based on Hosts, Interphase, and Electrolytes
Principal Investigator: Jun Liu (Pacific Northwest National Laboratory)

Presenter
Jun Liu, Pacific Northwest National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

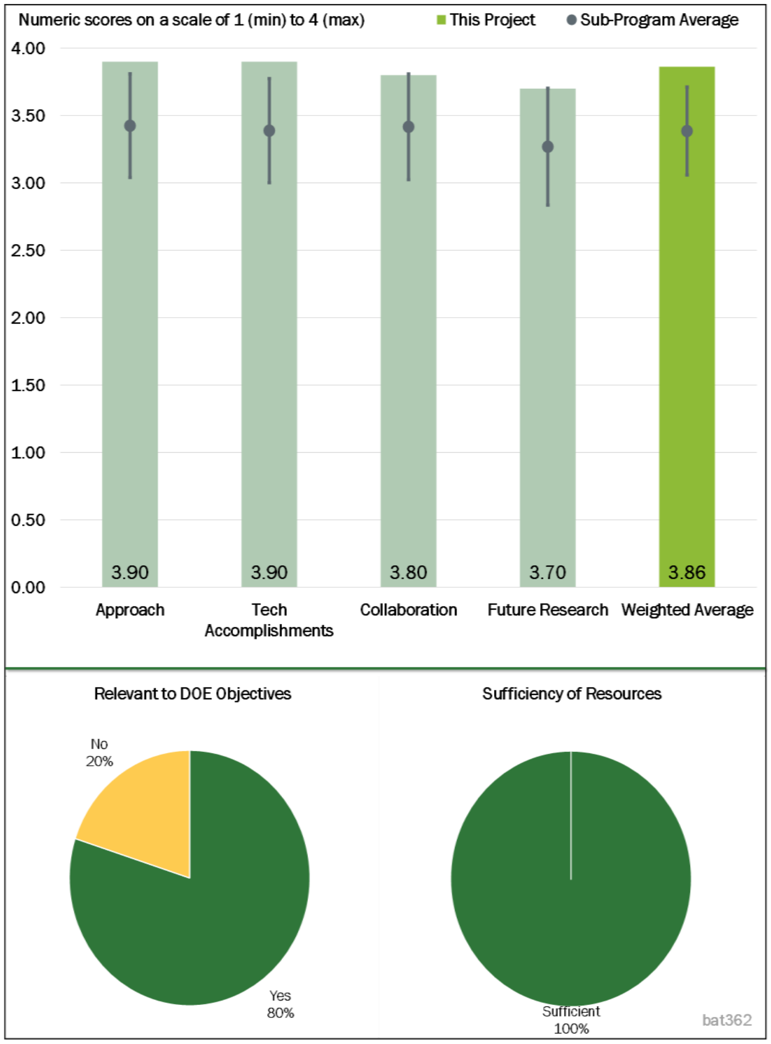

Figure 2-63 - Presentation Number: bat362 Presentation Title: Lithium-Metal Anodes: Problems and Multiple Solutions Based on Hosts, Interphase, and Electrolytes Principal Investigator: Jun Liu (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer said that the team has put in place a very comprehensive approach sharply focused on resolving the issues that plague Li anode cyclability. It is the best concerted effort the reviewer had ever seen to tackle this decades-old Li anode problem. This is a very carefully thought-out and planned project that is also implementable.

Reviewer 2:
The reviewer remarked that a localized high-concentration electrolyte (LHCE) approach is very well-designed. It retains all advantages of high-concentration electrolyte at a low cost. The reviewer praised that this is one of the best electrolyte works this reviewer has seen over recent years.

Reviewer 3:
The reviewer remarked that the team is attacking with three very good approaches—more stable electrolytes, improved protection layers, and new hosts. The team is also developing new methods to detect Li-metal.

Reviewer 4:
The reviewer said that the approach is highly comprehensive, including modeling and experiments in stable electrolytes, hosts for Li and S, protective layers, and detailed characterization.

Reviewer 5:
The reviewer said that the electrolyte additive and optimization are very important to achieving the stability of a Li-metal anode.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that significant progress seems to have been made towards improving the cyclability of the Li anode. Just to see cycle-life data up to 700 or so at reasonably high current density of 2 mA/cm^2 or so is quite refreshing and encouraging (please do show the data until the end so that people have a good idea about the failure mode). The reviewer said that it is very interesting to see how concepts like LHCE are significantly improving Li anode cyclability. The reviewer pointed out that quite a few novel ideas from the consortium labs are being explored, and the reviewer hopes that one of these ideas or a combination thereof will allow for the development of a practically useful Li cell.

Reviewer 2:

The reviewer observed a very sophisticated and innovative work to find an acceptable electrolyte with a high concentration, taking advantage of a deep understanding of ion transport. The reviewer is very impressed with how the team has combined theory and experiment to develop the improved electrolyte. The reviewer noted that experimental results are impressive, especially given that the experiments are not requiring high-cost surface engineering or high-cost additional steps in cell fabrication.

Reviewer 3:

The reviewer observed excellent progress demonstrated within a little more than one year.

Reviewer 4:

The reviewer said that the PI achieved the milestones and the progress is excellent.

Reviewer 5:

The reviewer remarked that accomplishments are numerous and impressive. The statement on one of the slides that the silly putty is “solid-like upon stress” is inaccurate. The reviewer said that it is solid-like under a high strain-rate.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found that the collaboration within the Battery 500 team seems strong.

Reviewer 2:

The reviewer noted an outstanding collaborative team that brings together scientists having complementary strengths is carrying out this project.

Reviewer 3:

The reviewer said that collaboration with other members of the team has been clearly demonstrated.

Reviewer 4:

The reviewer said that the PI actively collaborates with other teams within Battery 500.

Reviewer 5:

The reviewer said that the project would benefit from industrial collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer found that future work plans are clearly identified. This project will focus on developing 3-D host for Li-metal, and electrolyte additives. The reviewer pointed out that both are important for the Li-metal anode development.

Reviewer 2:
The reviewer said that the team is attacking the proper challenges.

Reviewer 3:
The reviewer observed that the team has proposed an exhaustive list of future work directed at improving the CE of the Li anode using the electrolyte concept, host structures, etc. These seem quite reasonable. The reviewer said that, however, the team should leverage lessons learned from other work as much possible to come up with a practically useful solution for this difficult problem. Working with systems that can be prohibitively expensive or difficult to manufacture or have not shown a robust solution should not be pursued for the sake of research alone. In this regard, the reviewer thought of very concentrated salt systems (cost), polymer coating (do they really work?), and vapor phase treatment of Li surface (manufacturability) among others.

Reviewer 4:
The reviewer commented that the desired attributes for protective layers for Li-metal electrodes should be identified and quantified to enable the project to go forward.

Reviewer 5:
The reviewer remarked that the PI may focus more on the fundamental understanding and optimization of LHCE and investigate the LHCE stability on the cathode side, especially when charging to higher voltage beyond 4.4V.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that this project supports the overall Battery 500 objective very well. It demonstrates an innovative approach to stabilize Li-metal, which is the key to achieving high energy density.

Reviewer 2:
The reviewer said that the Li-metal anode is the major issue to reach the energy density goal for the program.

Reviewer 3:
The reviewer pointed out that development of a well-functioning Li anode will be a major breakthrough towards the goal of the 500 Wh/kg cell that will directly support DOE's overall objectives.

Reviewer 4:
The reviewer found that the project supports the overall DOE Battery 500 objectives.

Reviewer 5:
The reviewer said energy density.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer found that the team has sufficient resources for the project.

Reviewer 2:
The reviewer said that the resources allocated should be sufficient to complete the tasks on schedule

Reviewer 3:
The reviewer said that resources for the project are sufficient to achieve the stated milestones in a timely fashion.

Reviewer 4:
The reviewer observed sufficient resources to carry out the proposed work.

Reviewer 5:
The reviewer said that resources are okay.

Presentation Number: bat363
Presentation Title: Understanding Performance Limitations in Thick Electrodes, Ping Liu
Principal Investigator: Ping Liu (University of California-San Diego)

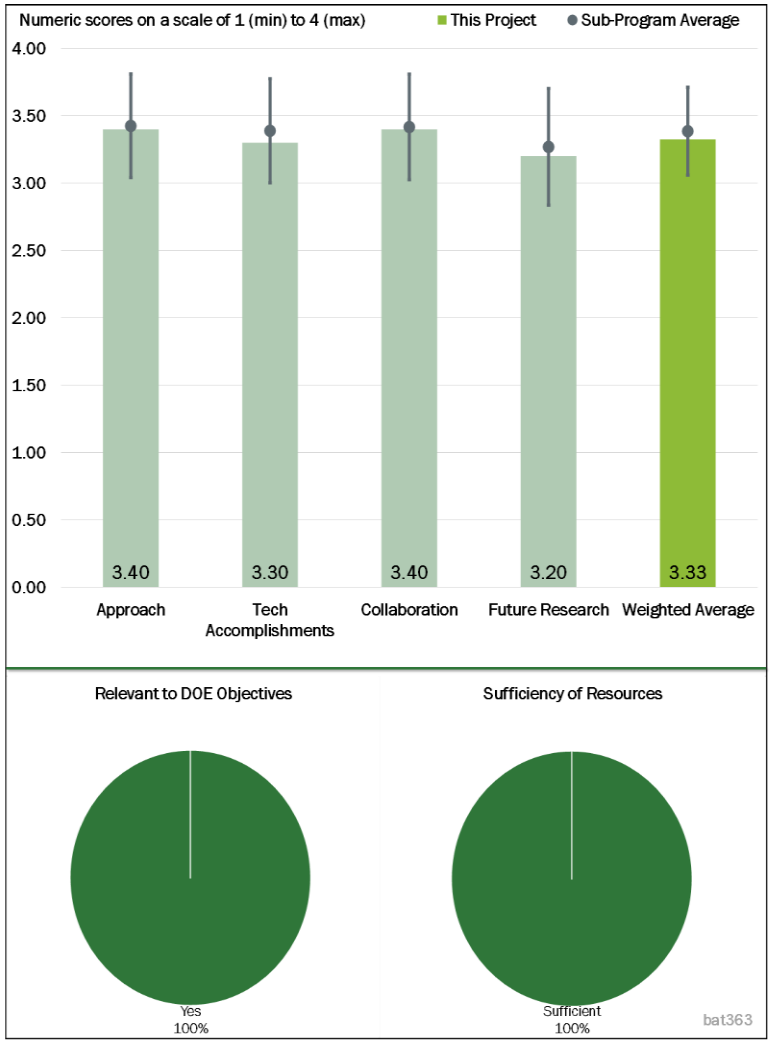

Figure 2-64 - Presentation Number: bat363 Presentation Title: Understanding Performance Limitations in Thick Electrodes, Ping Liu Principal Investigator: Ping Liu (University of California-San Diego)

Presenter

Ping Liu, University of California-San Diego

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the project is focused on the development of high loading cathodes by addressing factors that limit the performance of such electrodes. Effect of binders, use of open channels to enhance conductivity, as well as studies to delineate electronic and ionic conductivities are important aspects, among others, that need to understood to develop well-functioning thick electrodes

Reviewer 2:

The reviewer detailed that the goal of the overall Battery 500 project is to achieve a cell level specific energy of 500 Wh/kg through using high-capacity cathodes consisting of Ni-rich NMC or a S cathode, Li anode, and compatible electrolyte. High-capacity, Ni-rich NMC cathodes are being investigated by a few PIs in this project. However, a more likely solution, at least in the near-term, would be to develop thick electrodes to reduce amount of inactive materials to achieve proportionate gains in the specific energy. The reviewer said that analysis shows that this approach will also have a benefit in cost, because of the reduced quantities of separator, electrode substrates, etc. The challenge, however, is to ensure that the cathode is fully utilized through its depth, which requires cathode designs with low tortuosity, adequate electrolyte penetration etc., which this project is addressing. The reviewer found that this project is well designed and integrated with the goals and the other efforts under Battery 500.

The only difficulty with this approach is that several commercial (18650 cell) manufacturers have already achieved improved specific energies (greater than 50 wh/kg) with a dense cathode from state-of-the-art materials, and it is not clear if there is room for further improvements in this direction. The reviewer found that nevertheless, it is good that additional performance-governing paraments (ionic and electronic conductivity) are being evaluated with a dense cathode form industrial partners.

Reviewer 3:
The reviewer detailed that the project is trying to understand the thick electrode performance, and establish performance baseline for the 622 and 811 electrodes from various vendors.

Reviewer 4:
The reviewer said that the approach encompasses important goals, but it is quite vague. The reviewer asked how these goals are going to be attacked. This is more about characterizing, rather than optimization.

Reviewer 5:
The reviewer said that the project may need to identify more thick-electrode design parameters and study the effect of these design parameters (e.g., packing density, particle size distribution within electrode) on the electrochemical performance.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that the PI achieved the milestones and the progress is excellent.

Reviewer 2:
The reviewer remarked the team obtained quite a few interesting results that are helpful for designing thick electrodes. The coherent X-ray diffraction imaging (CXDI) results are worth noting along with work on the separation of electronic and ionic resistances of thick electrodes. The reviewer said that the 811 cathode image is impressive. The reviewer asked if the experiments can be done at higher temperatures to accelerate the degradation.

Reviewer 3:
The reviewer said that during the first year of the project, there seems to be two major accomplishments/findings: finding inhomogeneity in thick electrodes; and identifying the pros and cons of a “crack” approach.

Reviewer 4:
The reviewer found that good progress has been made on the NMC-622 and -811 cathodes in understanding the effect of loading on performance, in demonstrating good performance with dense (30 mg/cm^2) cathodes, and in verifying that these cathodes have structural stability but undergo structural reconstruction during cycling. Interestingly (but not unexpectedly) the poor utilization of the active material in a dense cathode has been verified from in operando CXDI imaging. However, whether it helps this in the design of thick cathodes was unclear to this reviewer, who asked whether it can be as quantify of electrochemical data. Ionic conductivity has been improved in dense cathodes (120 microns) by mud-cracking, but the electronic (contact) resistance has been found to increase. The reviewer said that it may be challenge to lower the ionic and electronic resistances simultaneously. The reviewer suggested doing the cathode design optimization with NMC 811 directly, instead of 622 (to avoid design modifications later on), provided suitable 811 or 900505 and with suitable particle size is available. Overall, this reviewer observed good progress in the first year of this project.

Again, based on this reviewer’s understanding, industry has achieved cathode a loading higher than 30mg/cm^2, though with NCA. The reviewer commented that it may be worthwhile to collaborate with a battery manufacturer, if possible. Also, DOE funded some projects in the past on developing thick cathodes. The reviewer asked if there is there anything to learn from them, especially 24M’s prior efforts.

Reviewer 5:
The reviewer said the team identified that binder is important, and that 811 structure is very robust. The reviewer was a little dubious about interpreting the inhomogeneity measurements. They seem pretty crude at

this point, but maybe the team can do better in the future. By only looking at a very small number of particles, the reviewer was unsure that the statistical power of the measurements is significant. BNL seems to have a much more quantitative approach. The importance of electronic resistance was demonstrated.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said that the team has excellent collaboration across the team members.

Reviewer 2:
The reviewer commented that there are very good collaboration activities with the PIs in the Battery 500 projects, with researchers from PNNL, UCSD, UT-Austin, and BU. The reviewer suggested more active collaboration with industrial battery manufactures and also with the national laboratories DOE previously funded for similar efforts.

Li, Zheng

The reviewer suggested that the PI can collaborate more with the materials synthesis team to study how the materials properties will impact the overall thick electrode performance.

Reviewer 3:
The reviewer commented that the samples seem to be provided by industrial partners.

Reviewer 4:
The reviewer said that the project would benefit from industrial collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that there are several outstanding issues with the dense cathode designs to reduce tortuosity without raising electronic resistance and to demonstrate long-term cycling stability in proper cells, without being limited by the Li anode, all of which will be addressed in the proposed future studies. These studies are consistent with DOE’s goals of high specific energy, low-cost, and safe Li-ion batteries.

Reviewer 2:
The reviewer said that the three approaches proposed in the “future work” section are important.

Reviewer 3:
The reviewer remarked that the proposed future research (electrode homogeneity, conductivity enhancement, etc.) look okay but the reviewer is unsure one can achieve the loading level that is the target of the Battery 500 program.

Reviewer 4:
The reviewer found that future projects are rather vague, although they are pointing in the right direction.

Reviewer 5:
The reviewer pointed out that Battery 500 proposed two chemistries. The future research should include work on designing S thick electrode and understanding the performance limitations.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer detailed that for a widespread use of EVs, the batteries need to be lightweight, compact, safe, and of low-cost. The state-of-the-art Li-ion batteries are inadequate to fulfil these needs. Higher energy density and lower-cost cathode materials are required to improve the specific energy for Li-ion cells and reduce overall cost for the battery. The reviewer said that the state-of-the-art cathode materials provide capacities of only ~170 mAh/g, which needs to be increased to greater than 220 mAh/g. Also, the cathode loading will have to increase by ~25% to achieve the cell level energy of 500 Wh/kg. The reviewer said that proper cathode designs are to be developed that will enhance ionic conductivity without impairing electronic counterpart, with the emerging cathode materials, which the present project is duly addressing.

Reviewer 2:

The reviewer commented that a thick electrode is essential to achieving high battery energy density, and that this project supports the Battery 500 objectives.

Reviewer 3:

The reviewer agreed that high cathode loading is definitely necessary to achieve the final program goal.

Reviewer 4:

The reviewer said that using thick electrodes minimizes cell cost and so this project has direct relevance to DOE's objective of a low-cost battery.

Reviewer 5:

The reviewer said high energy density.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the resources should be sufficient for the team to complete the tasks on schedule.

Reviewer 2:

The reviewer commented that the resources for the project are sufficient to achieve the stated milestones in a timely fashion.

Reviewer 3:

The reviewer said that resources seem to be sufficient to carry out the proposed research.

Reviewer 4:

The reviewer said resources are okay.

Reviewer 5:

The reviewer commented that the resources are adequate for the scope of the project, though it is not clear what the specific budget is for this group at UCSD (and individual organization in Battery 500).

Presentation Number: bat364
Presentation Title: Coatings for Cathode and Separator
Principal Investigator: Jihui Yang (University of Washington)

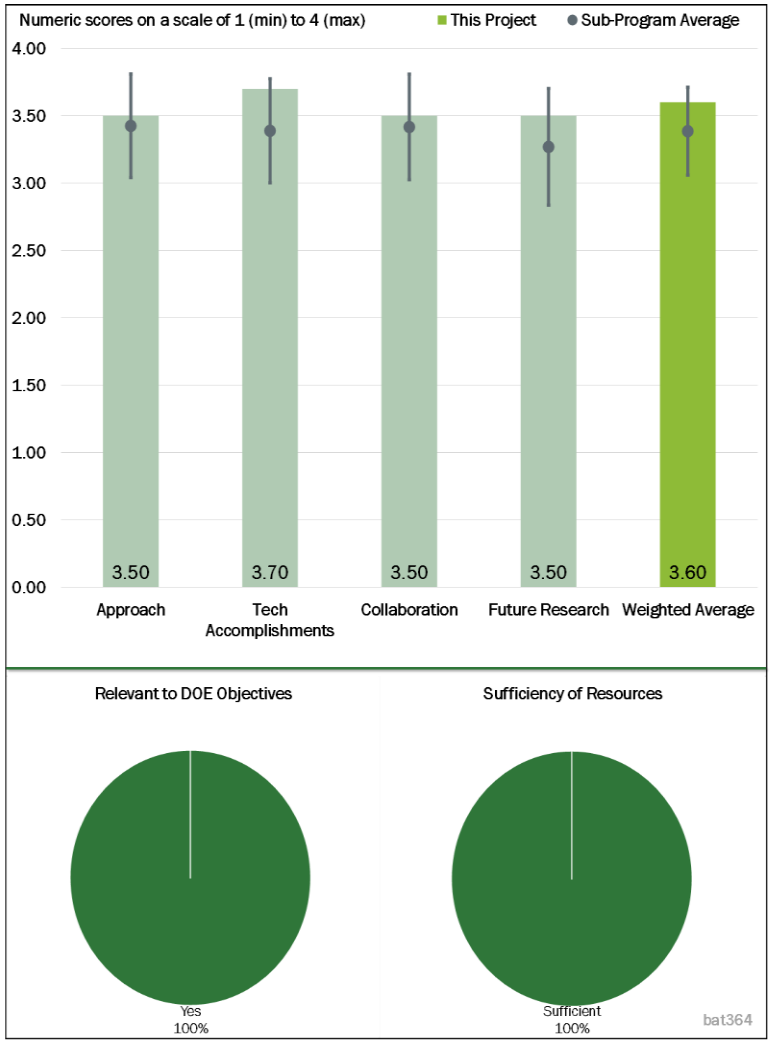

Figure 2-65 - Presentation Number: bat364 Presentation Title: Coatings for Cathode and Separator Principal Investigator: Jihui Yang (University of Washington)

Presenter
Jihui Yang, University of Washington

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer remarked that surface stability has been shown as one critical issue for the practical use of Ni-rich NMC cathodes in batteries. Surface coating via ALD appears to be an outstanding approach for protecting Ni-rich NMC cathodes from direct contact with the electrolyte and thereby improving the cycling stability. The reviewer said that the technical feasibility has been well demonstrated in this project, through extensive electrochemical tests and characterization using multiple techniques.

Reviewer 2:
The reviewer remarked that the approach is in-line with the Battery 500 technical challenges. The PI aims to tackle the interfacial problems of the NMC cathode and state-of-the-art separators with surface modification, and to combine the cathode and separators with a Li-metal anode. The reviewer remarked that the approach is appropriate and effective to improve the conductivity and uniformity of Li deposition, both of which are considered as the major technical obstacles for Battery 500.

Reviewer 3:
The reviewer commented that the team has done an excellent in studying the coatings for cathodes and separators in Li-ion batteries. The team has developed a mixed conductor surface coating for Ni-rich NMC materials to improve their interfacial and cycling stability. The reviewer pointed out the team has also identified a separator coating to improve the CE and cycling stability of a Li-metal anode. The project started in 2017 and has made remarkable progresses in addressing the technical barriers.

Reviewer 4:
The reviewer said that the approach with respect to synthesis and reactivity is good. The main technical barriers (particularly in the coated separators) will be centered around the mechanical properties. The reviewer

thought that perhaps more understanding of ceramic coated separators versus ceramic impregnated separators would be helpful.

Reviewer 5:

The reviewer summarized that the approach involves ALD coating on NCM cathodes in combination with solid electrolyte coatings on Li-metal to achieve high-energy density cells. The reviewer thought that while it is interesting and worth to be explored, it is unclear how this approach is different than similar approaches explored in other academic studies, why coating the separator may overcome the current limitations of the solid electrolyte coatings on Li foils (nearly all of which suffer from failures at grain boundaries), and if ALD coating is economical and fundamentally better than gradient commercial cathodes with solution-deposited layers.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the PI has made significant accomplishments in all three areas listed in the Technical Approach. The team tried different Al surface coatings and found that AlF_3 improved the cycle life of 811 NMC, which is the target cathode material for Battery 500; the separator coated with Li-ion conductive material can up-take more liquid electrolyte and establish an “artificial” SEI layer on a Li anode and therefore, reduce the dendrite growth on the Li anode. The reviewer said that the performance of the whole cell was improved.

Reviewer 2:

The reviewer said that the project milestones have been completed according to project plan and appear to be on track for next goals.

Reviewer 3:

The reviewer remarked that all of the milestones have been completed. Significant progress has been made in improving the interfacial and cycling stability of NMC811 by ALD coating. The reviewer commented that achieving 80% capacity retention for 300 cycles is outstanding. In addition, good progress has also made in ALD coating on separators.

Reviewer 4:

The reviewer remarked that the team has demonstrated several technical accomplishments and progresses toward overall project. The project is in good shape in terms of milestones. The reviewer suggested that tensile and penetration/puncture tests be carried out on the coated separators.

Reviewer 5:

The reviewer noted that the authors demonstrated in situ XRD to measure structural stability of 811; identified that the initially proposed sol-gel $LiAlO_2$ is not very effective (very high sensitivity to moisture; forming inert hydroxide and carbonates on the surface leading to high impedance); observed that ALD of AlF_3 on 811 particles (5-10 nm) improve cycling stability in half cells; and observed that thin coating (“30AlF^3) does not change diffusivity and rate performance, while thicker “60AlF_3” ALD coating does affect rate performance (in thick electrodes 7 mg/cm2). The authors observed that “regular”/”uncoated” NMC811 suffers from particle corrosion and metal dissolution. Finally, the authors found that LLZO and 5-10 wt. % polyethylene oxide with LLZO particles (15 microns in thickness) on the surface of a commercial Celgard separator show better performance than uncoated separators (although not nearly at the levels acceptable for use). The reviewer pointed out that many commercial 811 now show significantly better performance than what was demonstrated (which might be expected because industry invests in similar projects as well). Overall, the reviewer thought it would be beneficial if the authors would focus more on fundamentals and use ALD to tune coating chemistry systematically.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer observed a wide collaboration within the Battery 500 Consortium and externally (with GM), on materials synthesis/characterization and ALD coating, has been well demonstrated. One good example is the joint publications from the collaborations.

Reviewer 2:
The reviewer said that the PI intensively collaborated with PIs within Battery 500 and with an industry partner too.

Reviewer 3:
The reviewer remarked that the degree of collaboration is inherent in the Battery 500 consortium. It is a multi-pronged effort from many groups

Reviewer 4:
The reviewer commented that the authors collaborated with PNNL on separator coating and solid electrolyte modification, with GM on ALD coating of Ni-rich NMCs, and with UT-Austin and BU on Ni-rich NMC synthesis and characterization, including in situ XRD.

Reviewer 5:
The reviewer said that the PI has demonstrated several good collaborations with PNNL, GM, UT-Austin, and BU. The reviewer suggested that the PI reach out to collaborate with modeling groups to design the coatings.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that this is the middle of the second-year report. The PI presented a clear plan leading to the accomplishment of the on-going efforts of coating NMC811 cathode with AlF_3 and other materials, further optimization of separator coating. The reviewer said that the future work is based on the solid achievement of the project so far.

Reviewer 2:
The reviewer said that the proposed future work is well-planned. The reviewer suggested that the team study the bonding between the coating and the cathode/separator during/after cycling.

Reviewer 3:
The reviewer said that future research has been well-planned, on in-depth characterization of the surface ALD coating, and developing new coating materials/techniques. The reviewer said that more efforts are needed for integrating the ALD coating both on cathodes and on separators.

Reviewer 4:
The reviewer found that the proposed future research for cathode coating is reasonable based on results. The project is proposing to look at the mechanical properties of the separator coating. According to the reviewer, one area that is not mentioned is the adhesion of the coating to the separator, which could be a problem based on the mismatch of expansion properties of the ceramic versus the polymer.

Reviewer 5:
The reviewer detailed how the authors proposed to study three types of ALD coating on NMC811 (aluminum phosphate; $Li_{1+x}Al_xTi_{2-x}(PO_4)_3$ [LATP], and Li_3NbO_4; Mg-doped LATP, and zirconium -doped Li_3NbO_4);

optimize the separator coating morphology and reduce its thickness (less than 5 mm); and explore other separator coating techniques and conduct mechanical properties testing (puncture resistance, tensile strength, thermal stability, flammability, etc.). While all these sound interesting, the reviewer believed the project lacks systematic studies and a focus on fundamentals (e.g., how gradual changes in the coating chemistry and morphology affects its electrochemical properties in different electrolytes or other relevant structure-property relationships). Also, Li dendrite penetration and shortening a real cell in an EV has a very high chance to lead to a thermal runaway in the whole battery. The reviewer said that the probability of such scenarios must be reduced to the ppb level at the cell level to be commercially relevant. Increasing "cycling stability" before the dendrite shortens the cell is not sufficient to mitigate the risk of using Li-metal.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that the project addresses several points relevant to the Battery 500 goals (and more widely DOE objectives), including addressing surface reactivity of the high Ni concentration of the cathode, which will have to be addressed by a combination of cathode coating and electrolyte formulation.

Reviewer 2:

The reviewer commented that the research is closely related to DOE goals for high-energy batteries and lowering the cost. The fundamental research in this program will contribute to the accomplishment of the overall goals of Battery 500.

Reviewer 3:

The reviewer said that coatings for the cathode and separator (paid less attention before) are critical for the Battery 500 consortium team to triple the specific energy (to 500 Wh/kg) relative to today's battery technology and achieve 1,000 charge/discharge cycles.

Reviewer 4:

The reviewer found that this project, aiming at increasing cycling stability and high energy density at the cell level, supports the overall DOE objectives. The reviewer said the project has demonstrated a good balance of fundamental understanding and practical application.

Reviewer 5:

The reviewer pointed out that the projects aims to increase cell energy through exploration of new materials and processing techniques

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked that the PI and collaborators have fully used the resources at UW, PNNL, GM, UT-Austin, and BU.

Reviewer 2:

The reviewer found that the resources for carrying out the project appear to be sufficient.

Reviewer 3:

The reviewer said that PNNL and the Battery 500 partner institutions have sufficient resources for the proposed research.

Reviewer 4:

The reviewer noted that the Battery 500 consortium has pooled funding. The division of funds is not disclosed so no further assessment can be made.

Reviewer 5:
The reviewer said no idea, and elaborated that no information was provided for the budget of this particular project (as a part of the $10 million overall program).

Presentation Number: bat365
Presentation Title: Stabilizing Lithium-Metal Anode by Interfacial Layer
Principal Investigator: Zhenan Bao (Stanford University/SLAC)

Presenter

Zhenan Bao, Stanford University/SLAC

Reviewer Sample Size

A total of five reviewers evaluated this project.

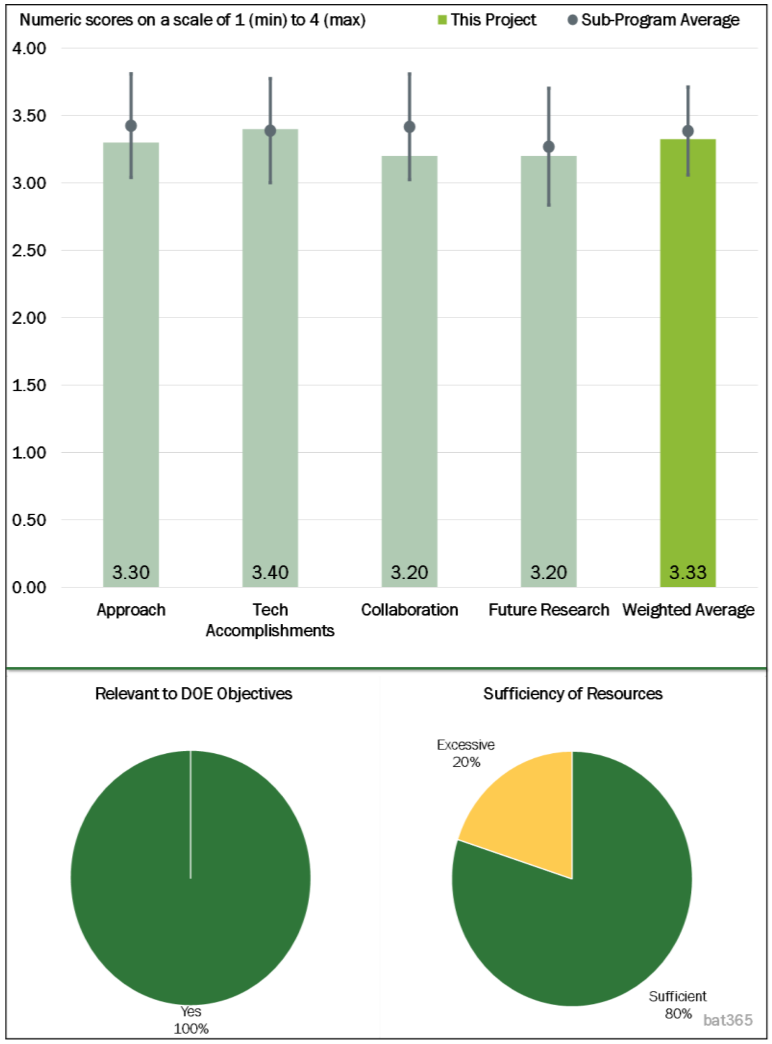

Figure 2-66 - Presentation Number: bat365 Presentation Title: Stabilizing Lithium-Metal Anode by Interfacial Layer Principal Investigator: Zhenan Bao (Stanford University/SLAC)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer detailed that in this project, surface coating of the self-healing polymer has been demonstrated to be effective in improving the stability of a Li-metal anode. This project shows a good balance of fundamental understanding and practical application, via combining design/synthesis of an interfacial protecting layer with structural characterization and electrochemical testing.

Reviewer 2:

The reviewer found that the approach is rational, it addressed the technical barriers such as dendrite growth and cycle efficiency.

Reviewer 3:

The reviewer remarked that the PIs are trying to develop an interfacial layer to protect the Li-metal surface. The approach includes fundamental material investigation of the material properties, synthesis of the material, and electrochemical tests. The reviewer said that the approach aims to prevent dendrite growth and extend the cycle life of a battery with a metallic Li anode. The approach can contribute to the goals of Battery 500. The reviewer said that the PI is encouraged to engage more discussion within the Battery 500 team; e.g., polymers in aqueous environment and in Li-ion electrolyte (protic and aprotic).

Reviewer 4:

The reviewer said that this project has a multi-pronged approach at SEI layer formation and characterization. The reviewer found that the weakness is that it is too broad and viable approaches may not be able to be fully explored. The reviewer pointed out that the ability to narrowly focus on positive results will be key for this to succeed.

Reviewer 5:

The reviewer said that the project aims to produce scalable coatings on Li foils to prevent Li dendrite growth and improve CE. The reviewer was unclear though exactly how the proposed project will overcome the shortcomings of the state of the-art. The project also aims to produce "light-weight host materials with high Li affinity for the fabrication of nanoporous lithium-host composite...." The reviewer was unclear again exactly what and how the PIs aim to accomplish this and how their approach is different/superior to prior art.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed that significant progress has been made in surface coating with the self-healing polymer, and all the milestones were met. Improvements in the cycling stability and reduced overpotential have also been achieved through polymer coating. The reviewer said that electrochemical tests in the full cells, with general electrolyte and NMC cathodes, may be crucial for validating the proposed coating approach.

Reviewer 2:

The reviewer said that by taking advantage of extremely advanced analytical instruments, the team investigated self-healing polymers as a dynamic coating for a Li anode. The results demonstrated that the polymers can rapidly heal a pinhole, and the coating can form uniform and less-porous Li on a copper substrate. The reviewer noted that a better cycle life was demonstrated in comparison with the control anode. The reviewer encouraged the PI try to deposit thicker Li deposition on a large electrode.

Reviewer 3:

The reviewer noted that a variety of novel approaches have been developed. It looked like most of the cycle condition is mild, including the current density and the areal capacity of Li in each cycle. The reviewer recommended that the team needs to include the test with practical test conditions as well in order to further validate their approaches.

Reviewer 4:

The reviewer said that some approaches need more data to illustrate if they are possible. For example, the self-healing polymer is an interesting idea, but the permeability is not well-described. The reviewer said that more attention to the electrochemical performance including rate capability would be helpful.

Reviewer 5:

The reviewer said that the project demonstrated multiple publications in the relevant fields. The efforts have been extremely diverse and overall quite interesting, but mostly at the very early "proof-of-concept" stages. The reviewer said that it would be more beneficial for the program if the efforts were more focused/concentrated and went deeper. The reviewer said that in this case, one may expect more meaningful technology developments, including collaborations with industry/commercialization partners (even at the expense of the number of publications), or more significant breakthroughs in fundamental understanding of the relevant phenomena.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that the degree of collaboration is inherent in the Battery 500 consortium. It is a multi-pronged effort from many groups.

Reviewer 2:

The reviewer said that the PI collaborates with researchers in multiple institutions. The reviewer encouraged the PI to enhance the interactions with Battery 500 team members, especially those with electrochemistry background.

Reviewer 3:
The reviewer said that it appeared that wide collaboration within Battery 500 consortium and externally (UCLA) has been established in this project. The reviewer suggested that maybe the PI needs to state more clearly how the collaboration was carried out.

Reviewer 4:
The reviewer said that it looked as though the interaction with other teams in Battery 500 is not enough. The reviewer thought that it is necessary to make the cell with the protected Li electrode, the best positive electrode, and electrolytes from Battery 500 teams to further improve the cycle efficiency and life.

Reviewer 5:
The reviewer detailed that collaborators included Dr. Mike Toney, Prof. Jian Qin, Prof. Reinhold Dauskardt, Dr. Steven Chu, Dr. Jun Liu, and Prof. Bruce Dunn. The reviewer was unclear though what collaborator assisted in what project and how such efforts were coordinated.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the future work is well-stated. Electrochemical tests in coin/pouch cells under the real electrochemical conditions, as planned in this project, will be an important step to validate the polymer coating in practical use.

Reviewer 2:
The reviewer said that the PI has an adequate plan to continue her research on the polymer material for coating and Li protection. The fundamental research was also suggested to understand the interfacial phenomena on Li anode. The reviewer thought that the proposed research can contribute to reach 350 Wh/Kg goal

Reviewer 3:
The reviewer found that the proposed future work is realistic. The reviewer thought that it would be great if the team can propose more collaboration with other teams and coordinate the efforts from different aspects.

Reviewer 4:
The reviewer remarked that future goals are a little broad.

Reviewer 5:
The reviewer summarized that future research for 2018 include: elucidating the critical parameters (chemical, mechanical, etc.) for polymers; fabricating polymer coatings for coin cells testing; and fabricating new polymer membranes. Overall, the proposed studies could make sense, but the reviewer was unclear how they may provide the needed breakthroughs and how they will be different from prior art. The lack of details is not helping the reviewers.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that this project, with the goal of stabilizing the Li anode and thereby enabling high-energy density and long cycling stability of Li batteries, supports the overall DOE objectives.

Reviewer 2:

The reviewer said that the work to enhance the Li anode performance is related to the DOE goal for high-energy batteries and cost reduction. The surface coating could mitigate the dendrite growth on metallic Li anode during cycling.

Reviewer 3:

The reviewer said yes, and elaborated that Li protection is critical to achieve 500 Wh/kg and long cycle life.

Reviewer 4:

The reviewer said that the targets proposed by DOE for Li-metal anodes require novel approaches and out-of-the-box thinking to solve issues like dendrite formation.

Reviewer 5:

The reviewer said that the project aims to overcome challenges with using Li-metal anodes for fabrication of lighter and smaller batteries.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that resources in this project appear to be sufficient.

Reviewer 2:

The reviewer said that the resources are sufficient considering the Battery 500 consortium already include some of the best battery researchers with broad expertise.

Reviewer 3:

The reviewer said that the combination of Stanford University and the national laboratories gives the PI more than sufficient resources to conduct her research.

Reviewer 4:

The reviewer was not clear what portion of the $10 million project went to the PI, but the reviewer assumed the resources were adequate

Reviewer 5:

The reviewer remarked that because the Battery 500 project has an overall funding, the individual project funding is not disclosed. It is difficult to assess whether individual project resources are adequate.

Presentation Number: bat366
Presentation Title: Advanced Imaging and Spectroscopic Study of Electrochemically Deposited Lithium Metal
Principal Investigator: Shirley Meng (University of California-San Diego)

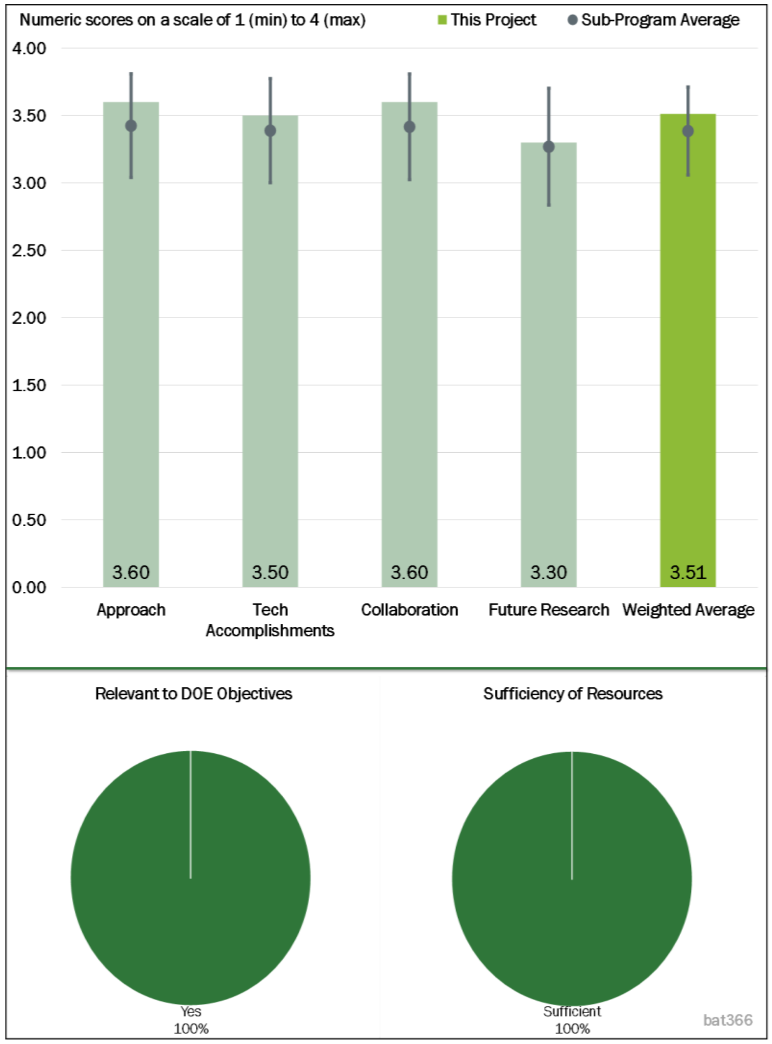

Figure 2-67 - Presentation Number: bat366 Presentation Title: Advanced Imaging and Spectroscopic Study of Electrochemically Deposited Lithium Metal Principal Investigator: Shirley Meng (University of California-San Diego)

Presenter

Shirley Meng, University of California-San Diego

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed a truly outstanding approach—using cryogenic techniques clearly provides unique insights and minimal artifacts.

Reviewer 2:

The reviewer found that the approaches to the problem are laid out well. The development of cryo techniques to understand both Li-metal anodes as well as SEI layer formation will be critical going forward.

Reviewer 3:

The reviewer said that the technical barriers have been well addressed. The SEI plays a crucial role for long-term cycle stability. Understanding the nature of SEI and Li-metal would dramatically help design the system and enable low-temperature performance.

Reviewer 4:

The reviewer detailed that the project is part of the Battery 500 project, which is aiming to achieve high specific energy of 500 Wh/kg at the cell level by way of using high-capacity Ni-rich NMC oxide or sulfur cathode, combined with a Li anode. The use of a Li anode for long-life cells is quite challenging of the limited cycle life, mainly due to the Li dendrites and “dead Li.” Specifically, this project focusses on utilizing the cryo-TEM to explore the nature of Li-metal and its SEI in order to improve the cycle life of Li-metal based batteries at room and low temperature. The reviewer said that to start with, electrochemically deposited lithium (EDLi) is being analyzed for its SEI in different low-temperature electrolytes. Cryo-TEM is an interesting and useful technique to examine Li and its surface conditions. The reviewer said that because of its reactivity, standard TEM cannot be used for Li. Recently, Stanford researchers reported the use of cryo-TEM commonly used for studying biological samples to examine the solid electrolyte interphase on Li and understand the interactions of Li with the interphase and captured the formation of dendrites. The reviewer thought that this technique will augment the traditional electrochemical techniques to verify the compatibility for Li-metal anode. Thus, according to the reviewer this project is well integrated with the efforts from other groups in the Battery 500 and its goals towards high specific energy of 500 Wh/kg at the cell level.

The reviewer pointed out that the dendritic behavior is exacerbated at high rates and low temperature charging. The reviewer asked if this technique is amenable to in situ studies involving low-temperature charging or rapid rate. For the ex situ studies to understand the SEI, it is not certain if the electrodes need to be washed or not.

Reviewer 5:

The reviewer observed that the approach using cryogenic electron microscope as a diagnostic tool is new in the investigation of Li anode surface and the SEI layer. The PI definitely developed a new technique to study metallic Li surface and overcome the drawback of traditional electron microscopes. The reviewer said that with the Cryo-TEM, not only the surface morphology, but also the dead Li can be investigated. The reviewer found that the approach could answer some very critical questions for the anode. The reviewer recommended that the PI should elaborate the impact of temperature change to the morphology of SEI layers.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the project team has demonstrated the effectiveness of the technique. The PI not only successfully applied the method to investigate the metallic Li anode, but also revealed the crystal structure and morphology at of SEI layer and Li formed under different conditions. The technique is proven as a new and efficient means to investigate the mechanism and understand the electrochemical phenomena on the Li anode surface.

Reviewer 2:

The reviewer commented that the accomplishments to date are impressive for this project. The particular focus relating CE to cycle life is the basic understanding which leads to project solutions. The milestones are on schedule.

Reviewer 3:

The reviewer pointed out that the promises of the proposed approach were experimentally demonstrated. The project team confirmed that room-temperature FIB introduces additional porosity, while cryo FIB/cryo TEM shows very clean images of Li-metal and its surface. Clear differences in the deposited Li and its SEI were observed when electrolyte additives were used or when the current density changed. The reviewer cited as a quite interesting example higher current density lead to the deposition of crystalline Li, while low current density lead to the deposition of amorphous Li. The reviewer cited as another very interesting observation the correlation between the CE and porosity of the deposited Li. It would be interesting to look into the fraction of the pores occupied by the SEI and if the Li losses per unit SEI volume are affected by the electrolyte composition or deposition conditions (temperature, current, etc.). The reviewer noted that a very novel liquefied gas electrolyte at ultra-low temperature showed very high CE (99.5 stabilizing efficiency and 92% first cycle efficiency) and also dense structure of the deposited.

Reviewer 4:

The reviewer noted that good progress has been accomplished in establishing the cryo-TEM technique at UCSD. Most of the data shown here are from the reported reports of Wang, et al on the capabilities of this technique in understanding the microstructure of Li, nanostructure of EDLi and identification of the SEI, and effect of current density and electrolyte additives on the crystallinity of Li and the SEI properties. The reviewer remarked that the studies performed in this project relate to the demonstration of good cycle life in electrolytes (from ARL) with high CE forming dense Li films. The reviewer found that overall, the progress is good based on difficulties associated with these fundamental studies, utilizing this new technique, and is consistent with goals of the Battery 500 project.

The reviewer pointed out that as with other diagnostic techniques, these studies, with this interesting technique, will be more useful if it can provide any insight in the designing of new stable electrolytes for a Li anode. Also, the reviewer asked what are the stable electrolytes developed for room and low temperature use (milestone 1). The reviewer asked if these are the fluoro-methane based liquefied gases, and do they have the stability compared to organic solvents.

Reviewer 5:

The reviewer said that TEM would give only localized information. Quite often, the information is not representative. The reviewer suggested that the team might need complimentary approaches to fully understand the structure and composition of SEI.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found that collaboration is excellent, involving the key players in this field.

Reviewer 2:

The reviewer noted excellent collaborations between partners: Electrolyte studies conducted in collaboration with Dr. Jason Zhang, Dr. Wu Xu, Dr. Jie Xiao, and Dr. Jun Lu (PNNL); Dr. Kang Xu and Dr. Marshall Schroder (ARL); Dr. Boryann Liaw (INL); cryo TEM studies conducted in collaboration with Dr. Elizabeth Villa (UCSD/Biological Sciences) and Dr. Xiaoing Pan (University of California-Irvine); and the work with the liquefied gas electrolyte was conducted in collaboration with Dr. Cyrus Rustmoji (South 8 Technology)

Reviewer 3:

The reviewer said that the degree of collaboration is inherent in the Battery 500 consortium, and said that it is a multi-pronged effort from many groups

Reviewer 4:

The reviewer said that there are good collaborations with the other PIs in the Battery 500 and with Dr. Xu's group (ARL).

Reviewer 5:

The reviewer said that the PI collaborates with the Battery 500 team members and researchers of other institutions.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the future research is well-laid out and specific enough for action.

Reviewer 2:

The reviewer said that there are a few outstanding technical barriers to correlate the nanostructure of EDLi and the CE, quantify the dead (passivated) Li, and to observe the plating and stripping process of Li-metal by in situ cryo-TEM and identify electrolytes that will provide stable interface and, finally demonstrate long cycle life with Li anode in test cells. The reviewer pointed out that there are several variables that control the propensity of dendrites including the nature of electrolyte (salt, co-solvent and especially additives), current density, temperature etc., all of which need to be adequately investigated. The reviewer concluded that these studies are logical, well-planned, and consistent with the goals of Battery 500 project.

Reviewer 3:

The reviewer said that the PI proposed to further optimize the cryo-TEM technique and study metallic Li, e.g., design of new holder. By means of the diagnostic tool, the PI also proposed to investigate the SEI layer formed under various conditions, the EDLi from different conditions, etc. The reviewer found that such fundamental research can contribute in significant ways to develop high-energy Li batteries proposed by Battery 500. The reviewer wondered that without knowing the cryo-TEM in details, if a “semi in situ” technique could be developed.

Reviewer 4:

The reviewer found that the proposed research sounds very reasonable. The reviewer expressed interest in seeing the detailed studies of the SEI composition; the portion of the pores filled by the SEI; the morphology and structure of the Li and SEI after more extensive cycling in different electrolytes (regular, hydrogen-free, fluorinated, ethers versus carbonates versus others, etc.); and the effect of the electrolyte (and SEI) composition and cycling conditions on the volumetric capacity of the SEI, etc.

Reviewer 5:

The reviewer recommended that the PI needs to correlate the cycle efficiency with dead Li, and design the ideal SEI accordingly.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer detailed that for a widespread use of EVs, the batteries need to be lightweight, compact, safe, and of low-cost. The state-of-the-art Li-ion batteries are inadequate to fulfil these needs. Higher energy density and lower-cost Li-ion cells are being developed under the Battery 500 project, specifically high-capacity cathodes, either Ni-rich NMC cathodes or sulfur cathodes which need to be integrated with stable Li anodes for achieving a cell level specific energy of 500 WH/kg. The reviewer said that to achieve long-cycle life without the risk of Li dendrites requires a fundamental understanding of the SEI on Li, which this project addresses, utilizing the newly-reported cryo-TEM. The reviewer found that thus, this project quite relevant to the overall Battery 500 project and its goals.

Reviewer 2:

The reviewer found that the project is highly relevant because it looks at the side reactions, which are present within batteries containing Li-metal anodes.

Reviewer 3:

The reviewer said that all the work is in-line with DOE’s need on the developing high-energy batteries and lowering the cost. The fundamental research in this program will be better understand the mechanism of, e.g., SEI formation under different additives, dead Li, etc., which will guide the development of an effective Li anode.

Reviewer 4:

The reviewer said yes, and elaborated that SEI is an enabler for the cyclability of a Li-metal electrode.

Reviewer 5:

The reviewer commented that the project addresses very important fundamental questions related to the morphology and composition of the deposited Li and SEI using cryogenic techniques.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the PI has adequate resources.

Reviewer 2:

The reviewer said that the resources are adequate for the scope of the project, though the reviewer was unclear what the specific budget is for UCSD (and individual organizations in the Battery 500 project).

Reviewer 3:

The reviewer noted that the team and collaborators have strong capabilities and expertise to make the project successful.

Reviewer 4:

The reviewer was unclear what portion of the $10 million went to the PI and collaborators. The reviewer is sure it is adequate, but does not have any detailed information to judge.

Reviewer 5:

The reviewer said that since the Battery 500 project has an overall funding and the individual project funding is not disclosed, it is difficult to assess whether individual project resources are adequate.

Presentation Number: bat367
Presentation Title: Integrated Characterization Studies of Battery 500 Consortium
Principal Investigator: Xiao-Qing Yang (Brookhaven National Laboratory)

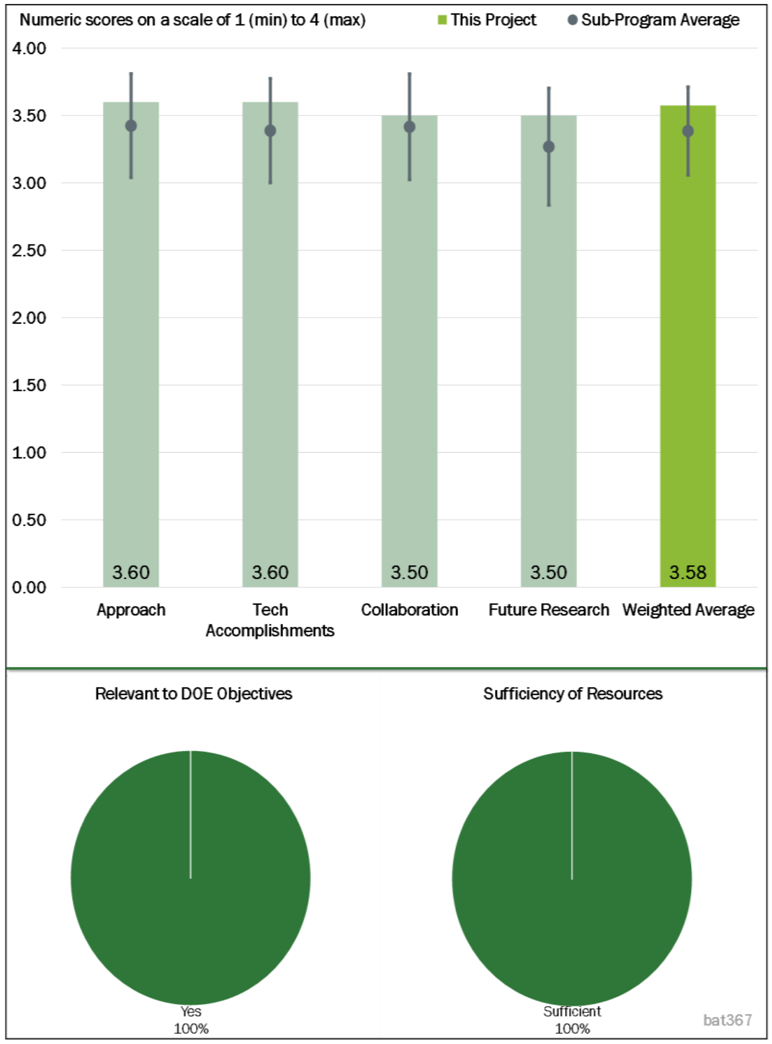

Figure 2-68 - Presentation Number: bat367 Presentation Title: Integrated Characterization Studies of Battery 500 Consortium Principal Investigator: Xiao-Qing Yang (Brookhaven National Laboratory)

Presenter

Xiao-Qing Yang, Brookhaven National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer detailed that this project is part of the Battery 500 project being led by PNNL aiming to develop a high-capacity Ni-rich NMC cathode with higher loading and S cathodes, as well as a stable Li-metal anode to get to a cell level specific energy of 500 Wh/kg. The reviewer described that this project is dedicated entirely to performing detailed characterization studies on the Ni-rich NMC cathodes to understand the structural and compositional changes during high rate charge-discharge cycles in thick cathodes; understand the rate-limiting processes and to design new cathodes with optimized composition, doping and surface coating; understand the thermal and cyclic stability of these cathodes and to improve the energy density and rate capability of cathode materials for Li-ion batteries; and examine the SEI properties on Li-metal anodes in conjunction with different electrolytes. The project is using various advanced characterization techniques: depth-profile XRD; STEM and electron energy loss spectroscopy (EELS) to study the structural changes of Ni-rich NMC; nano-probe beamline for micro-cracks formation and propagation; HRTEM and TXM for mapping high-Ni content cycling; and synchrotron-based, soft XAS (s-XAS) and scanning transmission X-ray microscopy for characterizing the SEI. This project complements and supports the material development efforts in Battery 500 projects and is a valuable component of the overall Battery 500. The reviewer found that this project is well-designed and planned and the techniques adopted here address the key technical barriers.

The reviewer commented that undoubtedly detailed and useful characterization studies are being done here on the Ni-rich cathode. However, these (dense) electrodes designs are far from being optimized, especially for high-rate discharges causing SOC gradient across the electrode. The reviewer believed most of these techniques are in situ, otherwise there is a dilemma on whether the electrodes need to be washed or not and its impact on the SEI characterization.

Reviewer 2:

The reviewer said that the development of new ways to look at old problems is critical to move forward. The connection between the structural anomalies and the electrochemical performance needs to be more fully elucidated.

Reviewer 3:

The reviewer said that the project involved using multiple unique capabilities, including TXM (to do 3-D reconstruction for the whole particle); and s-XAS, TEM, STEM, synchrotron XRD, XPS, modeling, nano-probe X-ray microscope at hard X-ray nano-probe beamline, etc. (to explore the fundamentals of NCM failures).

Reviewer 4:

The reviewer said that the PI's approach is to use the advanced analytical techniques, e.g., micro-focused beamline, STEM, EELS, nano-probe, X-ray neutron, TXM, etc., to study the crystal structure, oxidation state, and physical structure, e.g., porosity changes of an NMC cathode material (622 and 811) during the electrochemical charge and discharge. The reviewer said that the approach is synergistically related to the research and development tasks among the Battery 500 team, because the fundamental understanding through the diagnostic analysis can guide not only the material synthesis but also the electrode developments

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer pointed out that this is the middle of second year for Battery 500 program. The PIs have made significant accomplishments. The reviewer cited as examples the inhomogeneity of SOC, oxidation of Ni, etc. of a thick NMC cathode were quantified; and the pore distribution was also identified. The reviewer said that the conclusions can not only contribute to the fundamental understanding of the NMC cathode, but also be used to guide the development of the thick electrodes, which need to be adopted for high energy density.

Reviewer 2:

The reviewer commented that the technical accomplishments are impressive, particularly all the set-ups have been installed, which would provide a tremendous capability to understand the materials.

Reviewer 3:

The reviewer detailed that the team conducted in situ depth profiling studies using synchrotron based XRD to probe the inhomogeneity of thick NMC cathodes during cycling (which was interesting and informative) and mapped (SOC distribution. By using synchrotron based nano-probe TXM imaging studies, the team observed that Ni valence state exhibits a gradient from the surface to the bulk (more Ni^2+ on the surfaces and more Ni^4+ in the bulk, which is also interesting). The reviewer cited the also-observed cation inter-mixing at charged state and proposed that it may be correlated to the reduction of Ni^4+ resulting from oxygen loss. The team also detected micro-cracks formation in bulk (as was also observed by others) and found nano-sized pores formed in the center of the particles. Finally, the results of in situ synchrotron-based XRD studies on a Li-metal anode provided information about the amount of Li consumed and dead Li formed during cycling. Overall, the reviewer found most of the findings to be very interesting and the applications of advanced techniques quite admirable.

Reviewer 4:

The reviewer said that the technical milestones are on schedule. The ability to relate current technical accomplishments to battery performance is critical for project success.

Reviewer 5:

The reviewer said that good progress has been made in characterizing the structural, phase, and compositional changes in the bulk as well as at the surface of Ni-rich cathode. As may be expected, thick electrodes exhibit inhomogeneity in composition and SOC, especially at depths greater than 75 microns, even at moderate rates of C/3. Also, as with the previous NMC cathodes, the NMC811 exhibits a gradient in Ni valence state with the surface enriched in Ni^{2+}, while the bilk consists of Ni^{4+}. The reviewer further explained that nanopores and micro-cracks seem to be developed at the center of these cathodes during cycling, and finally spinel structures appear at high charge voltages. The reviewer found that overall, the technical data gathered here over the last year and half is quite good, and the progress made is consistent with the objectives of the Battery 500 project and goals of DoE.

While the reviewer acknowledged that these studies are no doubt impressive, the reviewer speculated that these observations are the same as with NMC32 and 611, or would they be notably different for the Ni-rich materials. The reviewer asked if it would be possible to quantify the degree of these changes, to compare and contrast the NMC cathodes with different Ni content.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said that the degree of collaboration is inherent in the Battery 500 consortium. It is a multi-pronged effort from many groups.

Reviewer 2:
The reviewer said that there are several useful and productive collaborations ongoing with several researchers within BNL and with the Battery 500 core team, especially with PNNL, UT-Austin, BU, BNL, INL, Stanford University/SLAC, UCSD, University of Washington, and also researchers from other DOE national laboratories (ANL), the ARL, and other universities.

Reviewer 3:
The reviewer said that the PIs collaborate with almost every member in the Battery 500 teams. In addition, the project team also works with other research institutions and industry.

Reviewer 4:
The reviewer said that it shows the excellent teamwork.

Reviewer 5:
The reviewer said that the authors collaborated with all institution members of the Battery 500 consortium and with Johnson Control Inc. The reviewer suggested that it would be informative to learn more about each specific collaboration, what it involved and how it was beneficial. Additional collaboration with automotive companies (at least receiving their feedback) would also be beneficial in the future.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the team proposed to complete the XAS studies of the high-Ni NMC cathode; complete the TXM studies of high-Ni NMC cathode multi-cycled at high voltage charge limit to understand the effects of high voltage cycling on the performance fading; develop neutron pair distribution function (n-PDF) to study the Li-anode and electrolyte interactions; and develop and apply synchrotron X-ray based in situ XRD to study the Li stripping and deposition. Overall, the reviewer found the plans to be excellent and the reviewer is looking forward to learning about the team's findings.

Reviewer 2:

The reviewer said that the future research, which revolves around the XAS and TXM of high-Ni cathodes with respect to high voltage cycling, should be a key piece of information to move forward with DOE objectives.

Reviewer 3:

The reviewer described that the challenges ahead for this project include developing in situ and ex situ characterization tools, e.g., synchrotron X-ray, neutron, and electron-based scattering, spectroscopic, and imaging tools to understand metal Li anode, i.e., monitor the SEI formation; the Li deposition process; the effectiveness of new additives, salts, solvents, as well as new electrolyte systems in suppressing the dendritic Li formation. The reviewer said that the proposed studies include completing the characterization of high-Ni NMC cathode multi-cycled at a high-voltage charge limit to understand the structural stability at high voltage charge and to develop nPDF to study the Li-anode and electrolyte interactions and synchrotron X-ray based in situ XRD to study the Li stripping and deposition process with different electrolytes and electrolyte additives. The reviewer said that these studies are relevant to the objectives and goals of Battery 500, are logical, and will address the key technical barriers associated with high-energy cells with Li-metal anode.

Reviewer 4:

The reviewer said that in the future, the PIs proposed to leverage the success in the investigation of the cathode and extend the techniques to metallic Li anode. The project team proposed to apply n-PDF to study the Li-anode and electrolyte interactions; develop and apply synchrotron X-ray based in situ XRD to study the Li stripping and deposition process under the conditions of various electrolyte additives; and Li/dead Li quantification. The reviewer said that the proposed work tackles the real challenges of a metallic Li anode, which is the central piece of the Battery 500 objectives.

Reviewer 5:

The reviewer pointed out that the team has proposed different approaches. For the future work, the coordination among those characterization techniques need to be further emphasized to gain a deeper understanding of the degradation mechanism, and most importantly to come up different solutions to solve the problems.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that the proposed research on the fundamental investigation of NMC cathode, Li anode, and electrode engineering, e.g., thick cathode, is critical to the development of high-energy, low-cost Li-ion batteries, which is directly related to DOE goals.

Reviewer 2:

The reviewer detailed that for widespread use of EVs and PHEVs, batteries with higher energy and lower cost than the current Li-ion batteries are needed, and the technologies based on a Li-anode with either high-capacity Ni-rich cathodes or S are expected to fulfil these needs with higher specific energy and proportionate cost benefits (from S or low-Co formulations). These high-capacity cathodes and the Li anodes have inherent technical challenges form the bulk and interfacial changes occurring during cycling, and new and advanced characterization techniques are needed to understand these changes. The reviewer found that this project is serving that purpose for the Battery 500 project and is consistent the objectives of Battery 500 and goals of the DOE-VTO program

Reviewer 3:

The reviewer commented that it appears that DOE objectives are leading to cathodes of higher Ni content operating at higher voltages. The basic understanding of structural and oxidation state changes will be necessary to determine feasibility.

Reviewer 4:

The reviewer said yes, a positive electrode is a critical component to achieve the energy density and cycle life of a Li rechargeable battery for Battery 500 goals.

Reviewer 5:

The reviewer said that the project aims to develop the advanced methodologies and gain deep fundamental knowledge needed in the development of high-energy density cells

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the PI has adequate resources to conduct the proposed research activities.

Reviewer 2:

The reviewer said that the resources seem to be adequate for the scope of the project. However, the funding information at various PIs under the Battery 500 project is not provided.

Reviewer 3:

The reviewer said that resources are sufficient, and that it would be great if the team can also include some modelling work at atomic scale to better understand the mechanism.

Reviewer 4:

The reviewer commented that because the Battery 500 project has an overall funding and the individual project funding is not disclosed, it is difficult to assess whether individual project resources are adequate.

Reviewer 5:

The reviewer could not determine if resources are sufficient (no data was provided on the budget given to this team out of the $10 million), but the reviewer assumed it is adequate.

Presentation Number: bat368
Presentation Title: Battery 500 Integrated Cell Diagnostics and Modeling to Identify Critical Gaps in Achieving High Cycle Life
Principal Investigator: Eric Dufek (Idaho National Laboratory)

Presenter

Eric Dufek, Idaho National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

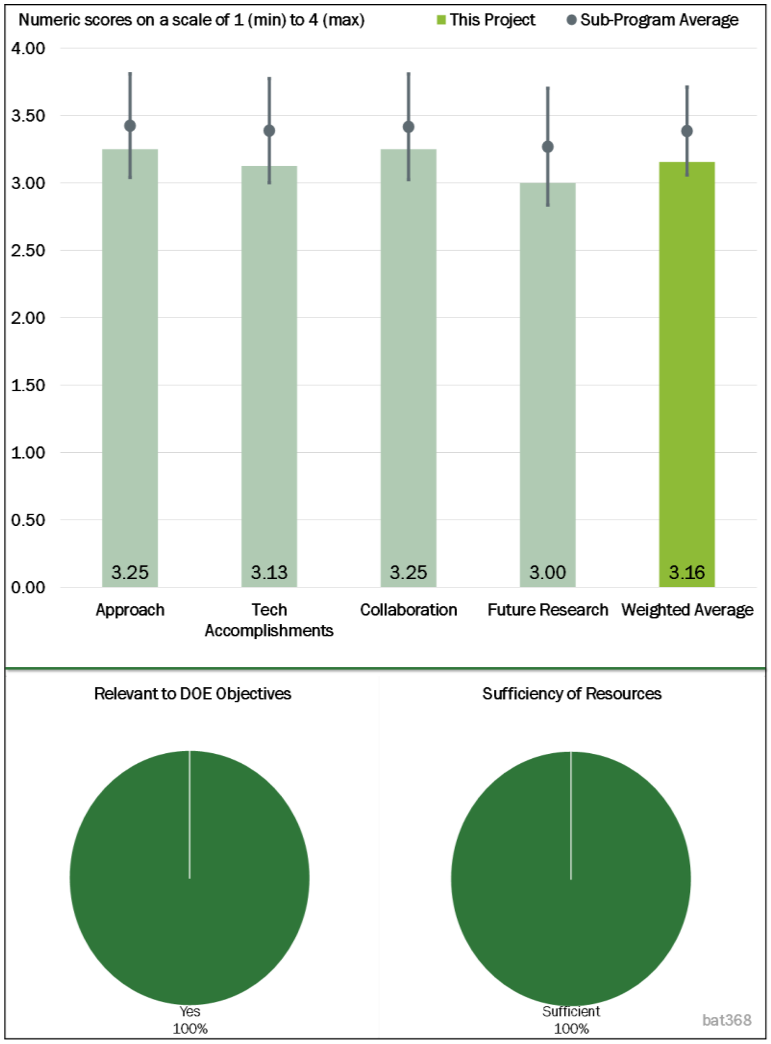

Figure 2-69 - Presentation Number: bat368 Presentation Title: Battery 500 Integrated Cell Diagnostics and Modeling to Identify Critical Gaps in Achieving High Cycle Life Principal Investigator: Eric Dufek (Idaho National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the importance of understanding the performance space of cell designs cannot be understated. The ability to have a consistent test vehicle is important to make progress particularly in a project that includes a large number of collaborators. The reviewer noted that this eliminates the confounding nature of cell design on the measurement of electrochemical performance.

Reviewer 2:

The reviewer said that the project is part of the Battery 500 project aiming to develop a high-capacity Ni-rich NMC cathode with higher loading and S cathodes as well as a stable Li-metal anode to get to a cell-level specific energy of 500 Wh/kg. Specifically, this project is examining the cell design options, such electrode thickness and electrolyte volume to maximize the specific energy with the Ni-rich NMC cathodes. The reviewer said that both coin and pouch cell designs are being optimized to utilize the evaluation of the high-capacity materials being developed in Battery 500. The reviewer found that this project is consistent with the other Battery 500 projects and with DOE’s goals. The reviewer said that modeling would be useful in understanding the transport limitations either in thick cathodes or in cells with depleted electrolytes. However, it is not as straightforward to expect the modeling studies to provide insights into the failure modes.

Reviewer 3:

The reviewer summarized that the project involves design and modeling of cells/electrodes to guide experiment, analysis, and diagnostics; tuning the electrode microstructure, studies; and the development of the methods to quantify failure mechanism and Li transport; and finally exploring routes to improve cycle life in high-energy cells.

Reviewer 4:

The reviewer commented that theoretically, the approach was in line with the goals of Battery 500, using modeling to guide experimentation, better understanding Li anode failure mechanisms, and proposing to improve the cycle life. All of those are critical for the development of high-energy Li batteries. However, according to the reviewer the PIs really lacked a comprehensive and feasible plan, e.g., the approaches are very generic and can be applied to any Li battery projects.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the measurement of the effect of electrode thickness and electrolyte content enables cell designs which can meet the project objectives in the Battery 500 group.

Reviewer 2:

The reviewer said that fairly good progress has been made standardizing fabrication procedures of coin cells and pouch cells, which would be helpful in evaluating the materials reliably across the different Battery 500 projects. The reviewer said that quantifying an electrolyte is crucial for Li-metal-based cells, and more so for Li/S cells to achieve adequate performance without harming the specific energy. Also, the performance of the Li/NMC (622) pouch cell, i.e., 160 cycles with the Li-metal anode, is encouraging, though the specific energy of 310 Wh/kg is not significant. The reviewer inquired if this pouch cell was fabricated at PNNL and tested here.

The reviewer posed related questions: What is consistency here, how many cells were tested, what is the spread in cycle life, and if there were there any early-stage failures common to Li cells. Further, the reviewer pointed out that adequate details are not provided in support of summary statements that analysis methods are in place to more directly correlate fade across program, and specific modeling activities were identified to focus on core areas for extending life and specific energy. Overall, the technical accomplished here over the last year and half are reasonable and the progress made is consistent with the objectives of the Battery 500 project and DOE goals.

Reviewer 3:

The reviewer pointed out that the PIs try to use Butler-Volmer equation as the core theory to model Li-ion system. Apparently, the results obtained cannot be very accurate because the model is too simplified. The reviewer could not understand the rational of the corrosion components in the model. The determinations of the sudden loss of ability for Li-ion transportation and the slow Li interfacial kinetics in a dQ/dV curves were a lack of support. The reviewer thought that the current distribution for the cathode of two different particle sizes is hard to understand. The reviewer suggested that the PIs overhaul the theoretical model; e.g., take into the consideration of ionic diffusion within the porous matrix and material with different defects or grain boundaries.

Reviewer 4:

The reviewer said that the authors observed significant cycle life reduction (by 10 times) when the team reduced the electrolyte 37 g/Ah to 6 g/Ah (not even that small as compared to commercial cells) in Li//NMC 622. The authors also introduced transport channels and reduced tortuosity. The reviewer pointed out that the authors also conducted modeling studies with dense Li-metal and porous cathodes (various particle size) and identified the need to minimize Li current density distribution to reduce Li dendrite formation. The reviewer characterized that the findings are interesting, but somewhat already known by many in the field. No major breakthroughs in technology or fundamental understanding have yet been achieved. The reviewer said that not many “out of the box” or very novel approaches have been explored.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the degree of collaboration is inherent in the Battery 500 consortium. It is a multi-pronged effort from many groups

Reviewer 2:

The reviewer said that there are good collaborations with several researchers within the Battery 500 project, especially with PNNL, and UT-Austin. Collaboration with other partners for the diagnostics may be forthcoming. The reviewer suggested collaboration with either ANL or ORNL for the pouch cell fabrication. Based on this reviewer's recollection, these two national laboratories have good experience/expertise with the pouch cell fabrication.

Reviewer 3:

The reviewer said that the PIs claim to have collaboration across the entire Battery 500 consortium. The reviewer suggested that the PIs go beyond conference calls and quarterly meetings, try to take advantage of the wide range of expertise within the consortium, so the model can be closer to reality.

Reviewer 4:

The reviewer appreciated that the team collaborated not only with multiple outside research institutions (INL, Stanford, SLAC, UT-Austin, UW, BU, UCSD, BNL) and conducted data/sample sharing, biweekly conference calls, quarterly meetings and joint publications, and also coordinated their activities with USABC, IBM, FMC, Naatbatt and Tesla. The reviewer said that it would be beneficial if the authors would clarify the contributions of each collaborator, and it would also be beneficial if the PIs would share feedback they received from industrial partners or at least specified their interactions.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that future proposed studies to further optimize the pouch cell design for identifying Li-metal failure and understanding the impacts of non-material cell influence, perform modeling studies to accommodate new materials and cell designs, and finally to understand the failure modes for the Li/NMC and Li/S through diagnostics are relevant, logical and will address the key technical barriers associated with the high energy cells with Li-metal anode.

Reviewer 2:

The reviewer said that the proposed future work fits well with accomplishments to date. The reviewer thought that it would be helpful to produce documentation with cell design recommendations to the battery community in general to standardize both test vehicles and protocol.

Reviewer 3:

The reviewer found that the proposed future research is important to the achievement of Battery 500 overall objectives, e.g., understand the failure mechanism, better material and design for cells. However, the future research plan is too generic and lacks contents

Reviewer 4:

The team proposed to identify Li-metal failure mechanisms and the impacts of external pressure, utilize realistic cell design parameters, and further coordinate modeling efforts with the introduction of new materials and designs into coin and pouch architectures. The reviewer found that overall, such project directions make sense, but the reviewer did not see its uniqueness as many research groups around the world are exploring similar areas. The description is not very specific, making it difficult to evaluate.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that modeling the electrochemical processes in Li cells is relevant to the Battery 500 goals.

Reviewer 2:

The reviewer said that the project contributes to the development of high-energy cells.

Reviewer 3:

The reviewer detailed that for a widespread use of EVs and PHEVs, batteries with higher energy and lower cost than the current Li-ion batteries are needed, and the technologies based on Li anode with either a high-capacity Ni-rich cathode or S is expected to fulfil these needs because of the enhancements in the specific energy and expected cost benefits (from S or low-Co formulations). A robust and efficient cell design to maximize the specific energy with Li anodes and either Ni-rich NMC or S cathodes and to demonstrate high specific energy are consistent with the objectives of Battery 500 and goals of the DOE VTO program

Reviewer 4:

The reviewer said that this project is a mandatory exercise needed to guide a large consortium of scientists.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer found that the resources seem to be adequate for the scope of the project. However, the funding information for various PIs under the Battery 500 project is not provided.

Reviewer 2:

The reviewer said that a national laboratory has adequate resources.

Reviewer 3:

The reviewer said that because the Battery 500 project has an overall funding and the individual project funding is not disclosed, it is difficult to assess whether individual project resources are adequate.

Reviewer 4:

The reviewer assumed resources are sufficient as no detailed budget was provided.

Presentation Number: bat369
Presentation Title: High Energy Rechargeable Lithium-Metal Cells: Fabrication and Integration
Principal Investigator: Jie Xiao (Pacific Northwest National Laboratory)

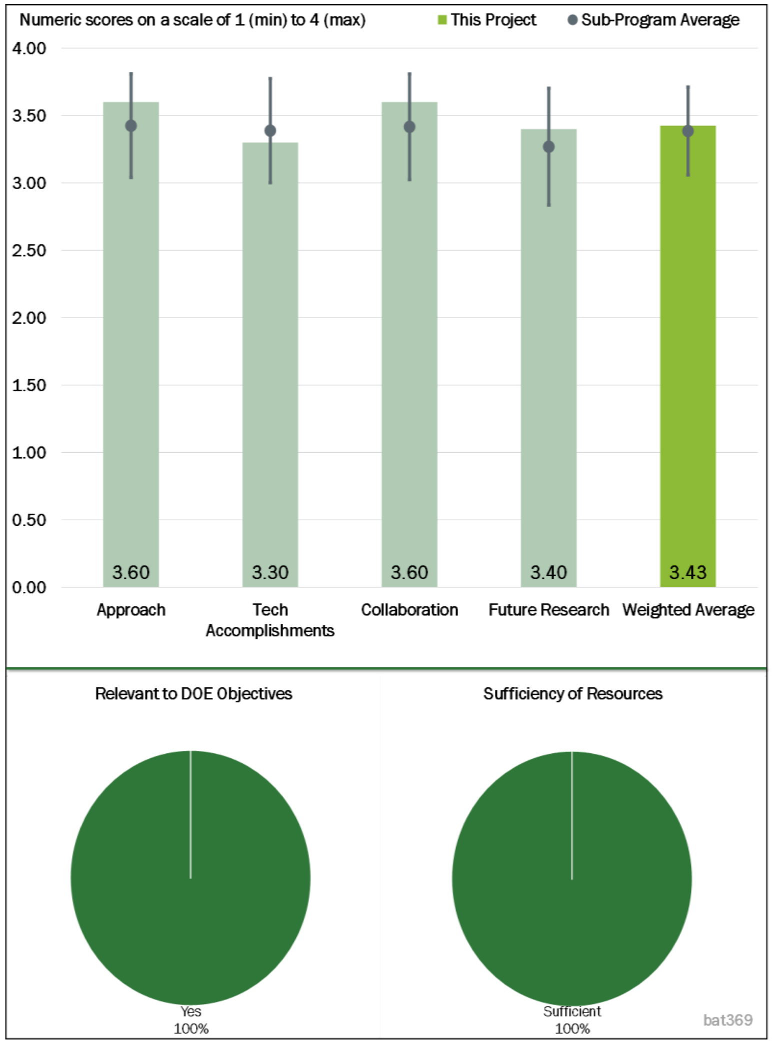

Figure 2-70 - Presentation Number: bat369 Presentation Title: High Energy Rechargeable Lithium-Metal Cells: Fabrication and Integration Principal Investigator: Jie Xiao (Pacific Northwest National Laboratory)

Presenter

Jie Xiao, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the approaches used in this project are novel and are showing some useful results with respect to cell failure versus electrolyte amount. This complements the work by Dufek group and contributes to the chemical component of the overall cell design.

Reviewer 2:

The reviewer said that the project is well-designed by considering closing the gap between academic research and industrial application. A lot of critical factors related with battery design for achieving high-energy density have been included in the approaches. The reviewer said that quite often, those factors have not been paid enough attention in the published literature. Standardizing the testing protocol within the Battery 500 consortium is very critical to integrate the advanced technologies together to achieve the 500 wh/kg target.

Reviewer 3:

The reviewer detailed that the objective here is to address the fundamental issues in fabricating and high-energy rechargeable Li-metal cells to achieve specific energy of 500 Wh/kg. The near-term (this period) objectives are to achieve 300 Wh/kg, with Li-metal and with S or a metal oxide cathode and a cycle life of more than 50 cycles. Apart from optimizing the design and fabrication methodology for long-life Li-metal based-pouch cells, and identifying the life-limiting processes, another important task here is the development of a new electrolyte for Li anode. The reviewer said that as planned, the project is well integrated with the projects under Battery 500. The reviewer remarked that coupling with the S cathode being developed by Cui et al, or with the Ni-rich, high-capacity cathode being developed by Manthiram et al will be beneficial for the Battery 500 project. According to the reviewer, it may also be helpful to collaborate with ORNL or ANL, where there is more experience and expertise with the fabrication of pouch cells.

Reviewer 4:

The reviewer said that Battery 500 uses a unique top-down approach to revisit fundamental challenges associated with Li-metal batteries. The PI broke down all the components of a 300 Wh/kg and identified key parameters affecting the cell-level energy. The reviewer said that the areal capacity, N/P ratio, and electrolyte content are found to be drastically different with common coin cell testing and significantly affect the observed testing results. The reviewer indicated that understanding the drastic difference between coin and pouch cell structures and testing conditions will be critical to this program and discover real challenges for battery research.

Reviewer 5:

The reviewer described that the team aims to conduct analyses to understand critical issues in high-energy Li-metal cells, develop new electrolytes to extend reversible Li cycling, and understand the difference in the performance gap between coin cell and pouch cell testing. Overall, the objectives make sense, but to the reviewer it was unclear what is innovative in the approach proposed and how it is different than what is being studied in hundreds of labs around the globe.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that this is the middle of the second year for this program. The reviewer acknowledged that the team has made many accomplishments. The PI successfully delivered a 300 Wh/kg Li-metal pouch cell with greater than 100 cycling (80% capacity retention). The team is also making great progress towards FY 2018 milestones, i.e., 350 Wh/kg Li-metal pouch cell with 100 stable cycling. More importantly, PNNL established standard testing protocol to close the gap between coin and pouch cell testing, which will ensure the fundamental research is conducted at relevant scale and greatly accelerate the research progress.

Reviewer 2:

The reviewer said that the progress is impressive, particularly, how to transfer the knowledge gained from coin cell to large format pouch cell. The reviewer said that this work provides the very useful guidance to academia and R&D work in industry.

Reviewer 3:

The reviewer said that fairly good progress has been made, especially in identifying the failure modes in pouch cells, standardizing the fabrication procedures for pouch cells (with limited electrolyte), and in, more importantly, developing a new electrolyte for Li anode based-cells, which shows good cycle life of ~100 cycles. The reviewer described that in most electrolytes, the SEI formed on Li anode is inadequate to protect it from further electrolyte reduction, thus resulting in a continued consumption of electrolyte and Li during cycling. Optimizing the electrolyte quantity is challenge in a Li pouch cell. The reviewer said that the new electrolyte, 1.5 M LiFSI-TEP/BTFE, seems to be more stable towards Li and is promising.

However, the reviewer asked if this electrolyte (being based on ether?) has the required oxidative stability at greater than 4V (the reviewer asked what its electrochemical window is). The reviewer also asked does the project require the development of a stable electrolyte for Li/S cells also, and is this electrolyte compatible with the S cathode and the polysulfides. The reviewer expressed surprise that the cycle life target for FY 2018 is so modest (50 cycles to 80% capacity). Overall, the technical accomplishments here over the last year and half are noteworthy and the progress made is consistent with the objectives of the Battery 500 project DOE goals.

Reviewer 4:

The reviewer found that progress towards milestones is adequate. The technical accomplishments to date have shown interesting results but need to be developed more to give a clearer picture of what Li depletion entails.

The reviewer thought that the graph showing Li depletion on Slide 10 shows an abrupt transition, which the reviewer did not expect from a chemical depletion.

Reviewer 5:

The reviewer said that the team observed dramatic expansion of Li-metal anodes after cycling and faster cell failure in pouch cells than in coin cells due to smaller electrolyte content (they all failed rapidly even at high N/P ratio of 2.6). The reviewer thought that this was an interesting observation, but many groups working with Li-metal anodes have known it for quite some time. The reviewer noted that in the course of another funded project the new electrolyte was introduced. The team used this electrolyte (1.5 M LiFSI-TEP/BTFE) and observed reduction in Li-metal swelling (compare 50 micron foils expanded to 205-320 micron after just 15 cycles in "regular" electrolyte to Li expansion from 50 micron to 150 micron in "new" electrolyte). The reviewer said that the study does not seem to be extremely systematic.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that PNNL is leading this program and has intensive interactions with all the team partners. PNNL's leadership and coordination are the key for the program to move forward. The reviewer said that they are doing a great job.

Reviewer 2:

The reviewer said that there are good collaborations with several researchers within the Battery 500 project, specifically with the researchers from universities, other DOE national laboratories, and industry. Being a complex problem, this development will need strong collaborations in verifying the proposed cell design modifications and new electrolyte for Li pouch cells, which is being done here.

Reviewer 3:

The reviewer said that the collaboration is excellent, involving national laboratories, universities, as well as industry. The coordination across the project team and the whole teams under the Battery 500 consortium is good.

Reviewer 4:

The reviewer indicated that the degree of collaboration is inherent in the Battery 500 consortium. It is a multi-pronged effort from many groups.

Reviewer 5:

The reviewer remarked that on the positive side, the collaborative activities have been quite outstanding. In particular, the reviewer appreciated the collaboration with industry (GM) on independent testing of PNNL's thick S electrodes and with Navitas System on a new coating method. The team also collaborated with nine universities and 3 national laboratories and clarified the nature of the collaboration very clearly.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that future proposed studies—to further optimize the new electrolyte and separator (for Li/S) to enhance the cycling stability of Li/NMC811 and Li/S pouch cells, improve the cell design for energy density and cycle life, and finally stabilize Li anode for improved cycling—will address the key technical barriers associated with the Li anode.

Reviewer 2:
The reviewer stated that the PI has a clear plan for future research. She has a map on the pouch cell level requirements and also knows well the fundamental problems of each key component. The reviewer said that all the proposed research is directly tackling the real challenges.

Reviewer 3:
The reviewer remarked that although the proposed future work is realistic, the deliverables listed could be more aggressive based on the accomplishments achieved in last year.

Reviewer 4:
The reviewer details that the team proposes to "Demonstrate 350Wh/kg pouch cell with >50 stable cycling and <20% fading" in 2018. This may be nice, but the reviewer was unclear what exactly the team aims to focus on to overcome major barriers and how the approach is innovative and different from their peers. For 2019, the team aims to conduct optimization of the new electrolyte for Li/NMC811 and Li/S pouch cells as well as to use coated Li (e.g., produced by Hydro-Québec). The reviewer found that such description is also very general and difficult to evaluate.

Reviewer 5:
The reviewer commented that the future research for 2018 is a target but no detail is given to the approaches to that target.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that the project contributes to increases in stability of Li-metal cells that offer higher energy density.

Reviewer 2:
The reviewer said that all the work is directly related to DOE's need on developing high-energy batteries and lowering the cost. The fundamental research in this program will be further validated in high-energy pouch cells, which is urgently needed in battery research field.

Reviewer 3:
The reviewer described that for a widespread use of EVs and PHEVs, batteries with higher energy and lower cost than the current Li-ion batteries are needed, and the technologies based on Li anode with either a high-capacity Ni-rich cathode or S is expected to fulfil these needs because of the enhancements in the specific energy and expected cost benefits (from S or low-Co formulations). A long-life Li anode is desired to meet DOE goals, which this project has been addressing. The reviewer detailed that the project is addressing two main technical barriers for EV batteries; i.e., low specific energy with the state- of-the-art Li-ion cells partly because of the use of carbonaceous materials with low specific capacity as anode. In contrast, Li-metal anode offers many-fold improvements in specific capacity and energy, but is hampered by short cycle life of ~50 cycles due to the dendritic nature of Li deposition and passivation. The reviewer said that this project addresses these barriers by specifically addressing the challenges in fabricating suitable pouch cells to demonstrate long-life with the Li-based cells. The reviewer found that the project is well-designed and planned to develop high-energy Li cells with S or metal oxide cathodes, consistent with the goals of DOE's VTO program.

Reviewer 4:
The reviewer commented that this project along with the Dufek group is a necessary contribution to a large consortium of scientists. This sets the "chemical" design for the batteries.

Reviewer 5:
The reviewer said that the work well addressed the barrier, and proposed work is closely related with DOE targets.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the teams in the Battery 500 consortium are the key players in this field. Their expertise and lab capabilities are in strong position to make the project successful.

Reviewer 2:

The reviewer said that though it is not what the budget is for this particular project ($10 million for entire Battery 500), the resources seem to be adequate for the scope of the project.

Reviewer 3:

The reviewer said that national laboratories have sufficient resources.

Reviewer 4:

The reviewer said that because the Battery 500 project has an overall funding and the individual project funding is not disclosed, it is difficult to assess whether individual project resources are adequate

Reviewer 5:

The reviewer assumed resources are sufficient, although no information was provided with the budget for this particular project.

Presentation Number: bat370
Presentation Title: Advanced Diagnostics of Nickel-Rich, Layered-Oxide Secondary Particles
Principal Investigator: William C. Chueh (Stanford University/SLAC)

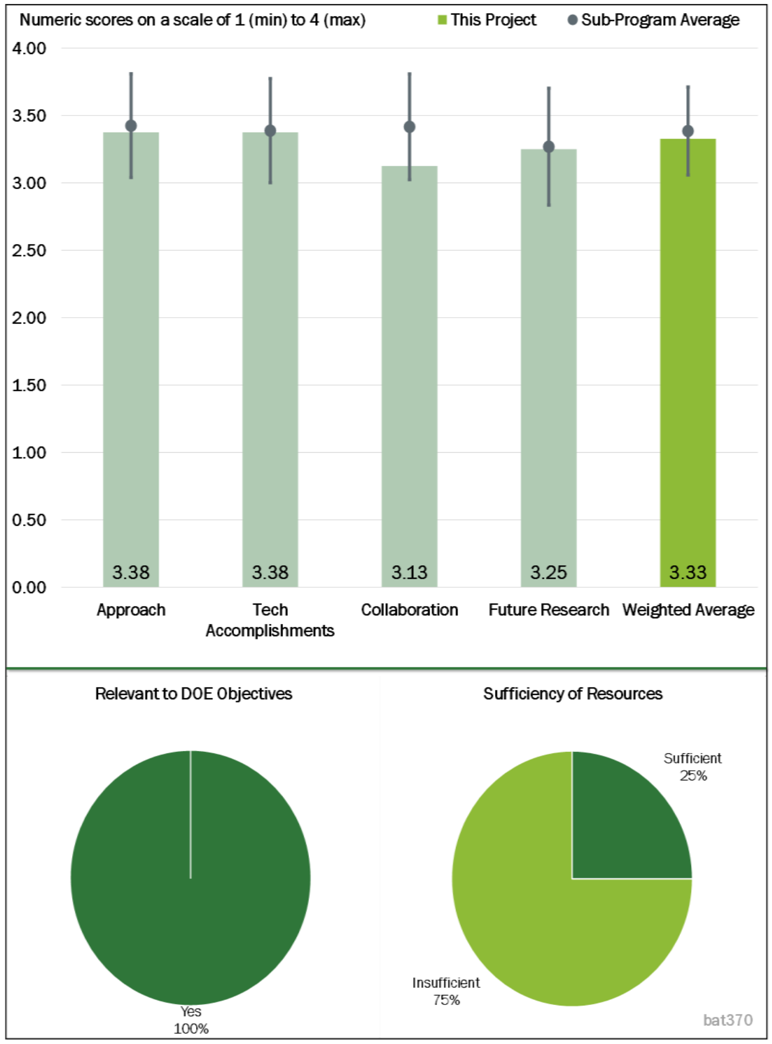

Figure 2-71 - Presentation Number: bat370 Presentation Title: Advanced Diagnostics of Nickel-Rich, Layered-Oxide Secondary Particles Principal Investigator: William C. Chueh (Stanford University/SLAC)

Presenter

William C. Chueh, Stanford University/SLAC

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the project team is developing an experimental set-up that will allow the team to measure mechanical changes to secondary particles and try to relate those data to crystallographic and electrochemical changes.

Reviewer 2:

The reviewer noted a very good and comprehensive approach to understanding fade in high-energy Li ion-cells. Excellent use of multiple diagnostics tools and good interpretation of results.

Reviewer 3:

The reviewer said that the approach taken is excellent. The PI is using a comprehensive diagnostic approach to understand the fading problems of high-Ni NMC cathodes at the atomistic through the mesoscale level. The effort is logical and appears to be well thought-out.

Reviewer 4:

The reviewer said that the project is focused on developing advanced characterization techniques to understand the chemical and microstructural changes in the electrode materials being developed in the Battery 500 project and correlate it with their cyclic stability (capacity loss), and thus guide the development of high-capacity cathodes. Specifically, the project aims to develop in situ and ex situ X-ray Spectro-microscopy technique to relate local chemistry and microstructure evolution in the cathode materials during cycling, manifesting from the electro-chemo-mechanical changes which will be probed at the relevant length-scales here. The reviewer said that these techniques are intended to correlate with other characterizations such as diffraction and electron microscopy. Thus, this project is well integrated with the efforts from other groups in the Battery 500 program.

The reviewer said that the evolution of microstructural evolution within the secondary particle due to the segmentation of the primary particles from the internal stresses due to de-lithiation would be a function of the electrolyte, which dictates the nature of SEI (or cathode electrolyte interface) on the primary particles. The reviewer thought that this study should be extended to the cathode's cycles in different electrolyte.

The reviewer pointed out that the benefit and relevance of this technique in understanding the microstructure evolution in cathodes is quite clear. The reviewer asked but how can this be extended to the imaging and diagnosis of Li-metal anode with different electrolytes and electrolytes additives, as indicated here (or it a different project in Battery 500).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that this is a small project to test a new technique. The team has made quite a bit of progress with just $10,000k. The team is relying on the fact that theirs is an anisotropic change in the structure that most likely results in strain in the primary particles and between secondary particles, and their techniques can detect in terms of changes to the secondary particles.

Reviewer 2:

The reviewer said that excellent progress has been made to date. The team developed 3-D transmission X-ray microscopy to characterize the evolution of internal pore structure and cracking in Ni-rich NMC as a function of voltage and cycling. The team also developed a sectioning procedure to prepare cathode samples for analysis. The reviewer noted that surprising results have been obtained. The formation of cracks and propagation occurs on the inside. The reviewer remarked that this finding is expected to spurn additional investigations by others.

Reviewer 3:

The reviewer affirmed that good progress has been accomplished in diagnosing the Ni-rich NMC cathode and establishing through operando XRD that there is a rapid collapse of c-lattice, increasing at high charge voltages greater than ~4.2V (as known with the conventional cathodes), which is reversible but yet causes structural degradation within (secondary) particle, but no such changes on the surface. The reviewer noted the team demonstrated that the locally induced stresses and accompanying SOC heterogeneity can lead to locally overcharged domains that are detrimental the cyclic stability. The reviewer found that overall, the progress is good based on the short duration of the project and also the low level of funding for this effort.

Reviewer 4:

The reviewer noted significant amount of good results. However, the PI correlates rapid capacity fade, and it is rapid, and mechanical cracking. Typically, industry is really good at watching for this (particle cracking, electrode failure) and making sure it is not there. But the PI still has a fairly rapid fade of 811 cathodes. Cracking is certainly an issue with some NMC particles, but it is not a major issue that the PI has seen.

The reviewer saw the multi length scale chemical imaging. The reviewer said got varying SOC both from particle to particle and within a single secondary particle, which is pretty amazing. There is decent driving potential in these NMCs.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the investigator has done a good job of bringing in other institutions to get access to the equipment needed.

Reviewer 2:

The reviewer said that there appears to be good coordination between the PI, co-PIs, and collaborators for the ALS and Stanford Synchrotron Radiation Light source. It was good to see that the users' faculties were at no cost to the effort.

Reviewer 3:

The reviewer found that there are good collaborations with researchers at Stanford, but may be extended to other PIs in the Battery 500.

Reviewer 4:

The reviewer noted reasonable collaboration, and that it might be valuable for the PI to collaborate with industry a little bit.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that this is a technique-development exploratory task. The PI is going to apply his technique to other systems to see if he can see something, like dead Li from cycling Li-metal.

Reviewer 2:

The reviewer believed that future efforts directed toward investigating cathode compositions that the Battery 500 team is pursuing is of great merit. There is no need for a thorough study of a material that will not be used. This type of support is necessary if the Battery 500 team is to meet the ultimate goals.

Reviewer 3:

The reviewer acknowledged that there are benefits in extending these studies from ex situ to in situ experiments, and to full cells to couple nanoscale electrode mapping to nanoscale crystallography in full cells. The proposed future studies will extend these studies to Ni-rich compositions investigated by Battery 500, to the cathode/electrolyte interphase chemistry, presumably as a function of electrolyte composition, using Spectro-microscopy for a quantitative understanding of the surface film and finally quantification of dead Li. These studies are logical, well-planned and consistent with the goals of Battery 500 project.

Reviewer 4:

The reviewer liked the future research, especially the quantification of the cathode/electrolyte interphase chemistry and the quantification of dead Li.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The project focuses on addressing one of the major problems. The USABC and the VTO have set aggressive battery performance targets that will require higher voltage and higher energy density than present Li-ion systems. Unfortunately, one of the most promising cathode materials, high-Ni NMC, has a limited cycle life. This effort is addressing this issue.

Reviewer 2:

The reviewer noted that as we move to higher energy, everything is being pushed to its extremes. The technique will be useful in measuring changes in cells.

Reviewer 3:

The reviewer said that high-quality diagnostics are always very relevant for pointing the way forward.

Reviewer 4:

The reviewer detailed that for a widespread use of EVs, the batteries need to be lightweight, compact, safe and of low-cost. The state of art Li-ion batteries are inadequate to fulfil these needs. Higher energy density and lower-cost cathode materials are required to improve the specific energy for Li-ion cells and reduce overall cost for the battery. The reviewer affirmed that new Ni-rich cathode materials with low microstructural degradation and low performance loss during cycling are to be developed, which the present project is duly addressing.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that resources are appropriate for the effort that is proposed.

Reviewer 2:

The reviewer guessed that the team is already spending more money than they are presently getting.

Reviewer 3:

The reviewer said that the resources seem to be inadequate for the scope of the project.

Acronyms and Abbreviations

°C	Degrees Celsius
1.5 M LiFSI-TEP/BTFE	Lithium-ion battery electrolyte
3-D	Three-dimensional
ABR	Applied Battery Research for Transportation
Ah	Ampere-hour
Al	Aluminum
ALD	Atomic-layer deposition
ALS	Advanced Light Source
AMR	Annual Merit Review
ANL	Argonne National Laboratory
ARL	Army Research Laboratory
ASIL	Automotive Safety Integrity Level
ASR	Area-specific resistance
ATR	Attenuated total reflection
BMR	Battery Materials Research
BNL	Brookhaven National Laboratory
BOL	Beginning of life
BU	Binghamton University
C	Charge rate
CAEBAT	Computer-aided engineering of batteries
CAMP	Cell Analysis, Modeling, and Prototyping Facility
CBD	Carbon-binder domain
CE	Coulombic efficiency
CEI	Cathode-electrolyte interphase
Co	Cobalt
CoEx	Co-extrusion
CT	Computerized tomography

D	Dimension
DEM	Discrete-element method
DEMS	Differential electrochemical mass spectroscopy
DFT	Density functional theory
DIC	Digital image correlation
DMC	Dimethyl carbonate
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
E/S	Electrolyte/sulfur
EC	Ethylene carbonate
EDLi	Electrochemically deposited lithium
EDS	Electric drive system, energy-dispersive X-ray spectroscopy
EDV	Electric drive vehicle
EELS	Electron energy-loss spectroscopy
EERE	Energy-Efficiency and Renewable Energy
EES	Electrochemical energy storage
EIS	Electrochemical impedance spectroscopy
EM	Electromagnetic
EUCAR	European Council for Automotive R&D
EV	Electric vehicle
FEC	Fluoroethylene carbonate
FOM	Figure of merit
FTIR	Fourier transform infrared spectroscopy
FY	Fiscal Year
g/cc	Gram/cubic centimeter
GaN	Gallium nitride
GM	General Motors
Gr	Graphite

GWh	Gigawatt-hour
HEV	Hybrid electric vehicle
HPC	High-performance computing
HRTEM	High-resolution transmission electron microscopy
HT	Heat transfer
HV	High voltage
I_0	Exchange current
ICL	Irreversible capacity loss
INL	Idaho National Laboratory
IR	Infrared
kg	Kilogram
kW	Kilowatt
kWh	Kilowatt-hour
LATP	$Li_{1+x}Al_xTi_{2-x}(PO_4)_3$
LBNL	Lawrence Berkeley National Laboratory
LCO	Lithium cobalt oxide
LFP	Lithium-iron phosphate
LHCE	Localized high-concentration electrolyte
Li	Lithium
Li_3NbO_4	Trilithium niobate
LiEDC	Lithium ethylene dicarbonate
LiPON	Lithium phosphorous oxy-nitride
LiS	Lithium-sulfur
LLS	Layered-layered spinel
LLTO	Lithium lanthanum titanate
LLZMO	Lithium lanthanum zirconium molybdenum oxide
LLZO	Lithium lanthanum zirconate
LMO	Lithium manganese oxide

LNMO	Lithium nickel manganese oxide
LNRO	$Li_{1.2}Ni_{0.2}Ru_{0.6}O_2$
LRLO	Lithium-rich layered oxide
LTO	Lithium titanate
mAh/g	Milliampere-hour/gram
MD	Molecular dynamics
MERF	Materials Engineering Research Facility
mg/cm^2	Milligram/square centimeter
mm	Millimeter
Mn	Manganese
Mo	Molybdenum
N/P	Ratio of negative to positive electrodes
Na	Sodium
Nb	Niobium
NCA	Nickel cobalt aluminum oxide
NCM	Nickel cobalt manganese oxide
NCMA	$Li_{1.0}Ni_{0.8}[Mn, Co, Al]_{0.2}O_2$
Ni	Nickel
NMC	Nickel manganese cobalt oxide
NMP	N-methylpyrrolidone
NMR	Nuclear magnetic resonance
nPDF	Neutron pair distribution function
NREL	National Renewable Energy Laboratory
OAS	Open architecture software
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PEO	Polyethyleneoxide
PHEV	Plug-in hybrid electric vehicle

PI	Principal Investigator
PLD	Pulsed laser deposition
PNNL	Pacific Northwest National Laboratory
PSU	Pennsylvania State University
PTFE	Poly(tetrafluroethylene)
PDVF	Polyvinylidene difluoride
R&D	Research and development
R2R	Roll-to-roll
$ROCO_2Li$	Lithium alkyl carbonate
S/cm	Siemen per centimeter
SEI	Solid electrolyte interface
SEISta	Silicon Electrolyte Interface Stabilization
SEM	Scanning electron microscope
Si	Silicon
SiC	Silicon carbide
SIMS	Secondary ion mass spectroscopy
SiO_x	Silicon oxides
SLAC	Stanford Linear Accelerator Center
SNL	Sandia National Laboratories
SOC	State of charge
SOH	State of health
SSE	Solid-state electrolyte
SSRL	Stanford Synchrotron Radiation Lightsource
SSRM	Scanning spread resistance microscopy
STEM	Scanning transmission electron spectroscopy
sXAS	Soft X-ray absorption spectroscopy
Ta	Tantalum
TEGDME	Tetraethyleneglycoldimethane

TEM	Transmission electron microscopy
TERS	Tip-enhanced Raman spectroscopy
Ti	Titanium
TiO_2-S	Titanium dioxide-sulfur
TM	Transition metal
TMPSi	Trimethoxypropylsilane
TTFP	Tris(2,2,2-trifluoroethyl) phosphite
TXM	Transmission X-ray microscope
U.S.	United States
UCLA	University of California at Los Angeles
UCSD	University of California at San Diego
USABC	U.S. Advanced Battery Consortium
UT-Austin	University of Texas at Austin
UV	Ultraviolet
V	Volt
VIBE	Virtual integrated battery environment
VTO	Vehicle Technologies Office
WBG	Wide bandgap
Wh	Watt-hour
Wh/kg	Watt-hour per kilogram
XAS	X-ray absorption spectroscopy
XPS	X-ray photoelectron spectroscopy
XRD	X-ray diffraction spectroscopy
Zr	Zirconium
ZrO_2	Zirconium dioxide (zirconia)

3. Energy Efficient Mobility Systems

To strengthen national security, enable future economic growth, support energy dominance, and increase transportation energy affordability for Americans, the Vehicle Technologies Office (VTO) funds early-stage, high-risk research. The research will generate knowledge that industry can advance to deploy innovative energy technologies to support affordable, secure, reliable and efficient transportation systems across America. VTO leverages the unique capabilities and world-class expertise of the national laboratory system and works with partners across industry and academia to develop new innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures and better powertrains; and energy efficient mobility technologies and systems, including connected and automated vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement. VTO is uniquely positioned to address early-stage challenges due to its strategic research partnerships with industry (e.g., the U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise. These partnerships prevent duplication of effort, focus U.S. Department of Energy (DOE) research on the most critical research and development (R&D) barriers, and accelerate progress. VTO focuses on research that industry either does not have the technical capability to undertake on its own—usually because there is a high degree of scientific or technical uncertainty—or it is too far from market realization to merit sufficient industry emphasis and resources.

The Energy Efficient Mobility Systems (EEMS) subprogram supports early-stage research to enable industry innovation that improves the efficiency of the overall transportation mobility system. Initial analysis by DOE indicates that the future energy impact of connected and automated vehicles (CAV) is highly uncertain and may be quite large, ranging from a potential 60% reduction in overall transportation energy use to a 200% increase in energy consumption. EEMS will apply complex modeling and simulation expertise, experience with big data, and high-performance computing (HPC) capabilities unique to DOE national laboratories to explore the energy impact of emerging disruptive technologies such as CAV, information-based mobility-as-a-service platforms, and advanced powertrain technologies to identify and develop innovative mobility solutions that improve energy efficiency, lower costs for families and business, and enable the use of secure, domestic energy sources. The EEMS subprogram consists of two primary activities, the SMART Mobility National Laboratory Consortium and HPC-enabled data analytics, which build upon VTO's work in advanced powertrains, controls, and electric vehicle (EV) charging. The subprogram's overall goal is to identify pathways and develop innovative technologies and systems that can dramatically improve mobility energy productivity when adopted at scale. The EEMS subprogram is currently developing a quantitative metric to measure mobility energy productivity, or the value derived from the mobility system per unit of energy consumed, which will be required to evaluate program success.

Subprogram Feedback

DOE received feedback on the overall technical subprogram areas presented during the 2018 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied.

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year?

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: eems918
Presentation Title: Energy-Efficient Mobility Systems (EEMS) Overview
Principal Investigator: David Anderson

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:
The reviewer responded positively and commented that the Program Manager did a great job explaining the overall strategy and structure setting up successful environment for oral and poster presentations from the team.

Reviewer 2:
The overall program objectives were very clear to this reviewer, who also noted a detailed overview of the program.

Reviewer 3:
This reviewer stated yes.

Reviewer 4:
The reviewer thought that the program area, including overall strategy, was adequately covered. Further, the Program Manager expressed a lot of passion for such a new area of emphasis to the U.S. Department of Energy (DOE) that this reviewer described as very refreshing.

Reviewer 5:
This reviewer remarked that the program area overall was covered well and noted that the current high-level strategy was discussed in pretty broad terms. Although there was sufficient content at the highest levels, and sufficient content at the most detailed, project accomplishment levels, there did not seem to be the bridging slides between the two levels that the reviewer hoped to see.

Reviewer 6:
The reviewer indicated yes, in part, but could not understand how the various program initiatives connected together for the greater goals of the EEMS program. As a staunch believer in system understanding of technologies, this reviewer did not hear from the presentation about the chosen systems that need to be solved and inquired about the following: whether they are light-duty, and if so, what are the goals of light-duty improvement; whether they are related to emissions, travelled miles, or travel time; whether there is a goal for freight efficiency and what is the definition of that system; and whether they are based on carbon dioxide (CO_2) reduction, tonnage moved, or cost.

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Reviewer 1:
This reviewer observed an excellent balance that showed the value this newer group brings to the rapidly changing technology environment.

Reviewer 2:
Although difficult with such a new area, the reviewer thought that there was an appropriate balance between near-, mid-, and long-term research and development. The reviewer referenced last mile comments that show the importance of analyzing longer-term opportunities sooner to avoid getting boxed into something undesirable down the road.

Reviewer 3:

The reviewer commented that there was not a lot of information presented on how the goals are different between near-, mid-, and long-term. The three strategic goals were listed, but the reviewer indicated that there was a gap with the envisioned stages, phases, and timing for meeting each of these strategic goals.

Reviewer 4:

This reviewer remarked that the push for vehicle connectivity and mobility is at a fast pace and noted the important of having data with respect to driver behavior. Although the balance is there, the reviewer expressed concern that the infrastructure is lagging.

Reviewer 5:

The reviewer opined that more near-term development would have been better; too many of the high impact items are at the end of the program or classified as future work.

Reviewer 6:

Timing of the research was difficult for this reviewer to ascertain from the presentation material. A general categorization of technology readiness level (TRL) status was not presented, but the reviewer suggested this could be helpful in the future.

Question 3: Were important issues and challenges identified?

Reviewer 1:

Considering the current conditions, this reviewer indicated yes and added that important issues and challenges were identified very thoroughly.

Reviewer 2:

This reviewer stated yes; modeling and accurate sensitivity analysis are important and the impact of rideshare and autonomy is essential. Accessing real commercial data is difficult, but the reviewer opined that it is important to avoid drawing the wrong conclusions.

Reviewer 3:

The reviewer remarked yes and explained that a variety of issues and challenges were presented, which mostly reflected light-duty automotive transportation. The reviewer recommended that more information regarding public transportation and freight movement should be defined.

Reviewer 4:

This reviewer was unsure and commented that important issues and challenges may emerge more concretely over the next few years.

Reviewer 5:

Issues and challenges were not really addressed in the presentation, though this reviewer strongly suspected that these are articulated in detail within each of the projects in the Energy Efficient Mobility Systems (EEMS) space. The broad challenge that the reviewer thought should appear in this presentation was how the projects are broadly planning to influence future implementation. It came across more as, “We think all of these analyses are important to complete because connected autonomous vehicles (CAVs) and mobility are the future direction in transportation,” but the presentation was missing the “why” these are being completed and the “how” they will be used to influence policy, original equipment manufacturers (OEMs), standards, etc.

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:
The reviewer responded positively and offered the Program Manager’s comment on rapid disruptive change as an example. This reviewer noted that transportation options are immense and that charts were helpful in the Program Manager’s messaging concerning CAVs.

Reviewer 2:
This reviewer responded that the presentations were clear on identifying the challenges and described available data to support integration of the technology as a main one. The connected vehicle protocols and standards are not mature yet and the reviewer commented that this is an area needing more focus.

Reviewer 3:
The reviewer stated yes and described the presentation as clear and relatable, highlighting the enjoyable soccer team comparison.

Reviewer 4:
Other than listing some of the example projects and initiatives, this reviewer indicated that there were not many plans able to be reviewed given the short presentation timeframe.

Reviewer 5:
This reviewer opined that plans for addressing issues and challenges were not really identified because issues and challenges were missing from the presentation in the first place and as far as the reviewer could discern.

Reviewer 6:
The reviewer could not see that plans were identified for addressing issues and challenges.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:
This reviewer indicated yes; evolution is highlighted with the addition of the Integration Team.

Reviewer 2:
The reviewer observed a series of example accomplishments mentioned from specific projects, but there was not really a progress report at the program level. Also, the reviewer explained that there are really two ways of benchmarking this progress: use where the performance year started as the baseline and report out on accomplishments since that baseline; or quantify the accomplishments reported at last year’s AMR and compare them to this year’s accomplishments. This reviewer concluded that the presentation showed more of the former, but could benefit from more content within both the former and considering incorporation of the latter.

Reviewer 3:
This reviewer noted more awareness of connected vehicles and better understanding of driver behavior and acceptance.

Reviewer 4:
Although the reviewer commented that progress was not really clearly benchmarked against the previous year, the reviewer acknowledged that the program is so new.

Reviewer 5:
The reviewer responded negatively, but indicated that this appears to be a relatively new program.

Reviewer 6:
This reviewer stated no.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:
This reviewer thought the projects in this technology area align with the larger scope of VTO objectives.

Reviewer 2:
The reviewer indicated yes; this is a system level area versus technology ones such as batteries. Further, this reviewer noted that it was good, important, and helpful to share vision, mission and goals. The Program Manager spoke quickly and with obvious passion. Although the reviewer knew that the Program Manager wanted to catch up some time, it was not his fault that the program was more than 20 minutes behind.

Reviewer 3:
This reviewer asserted that the EEMS group can play the key role in evolving the work of other VTO groups into real-world solutions.

Reviewer 4:
The reviewer stated yes.

Reviewer 5:
This reviewer remarked yes, largely; the broad problems and barriers are addressed, overall, but weaving in the safety constraints and metrics remains a gap. It would have been beneficial to see a high-level articulated strategy with phases showing how each individual project feeds into an overall approach. For example, the reviewer was unsure how much overlap there was in models or problem statements to assess this well.

Reviewer 6:
Referring to Question 1 and a lack of the overall program objective definitions, the reviewer answered that it was hard to tell. However, this reviewer noted that there appeared to be an interesting set of projects dealing with many aspects of mobility systems.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:
The reviewer remarked yes; there is a feel for having a good understanding of what needs to be done, especially in the one-on-one exchange.

Reviewer 2:
This reviewer indicated yes and observed good modelling integration work and data analysis.

Reviewer 3:
This reviewer commented yes and opined that the Program Manager is passionate about the vision and knows the importance of teamwork. This came through well in the Program Manager's presentation.

Reviewer 4:
The reviewer stated yes.

Reviewer 5:
This reviewer described the program area as very focused. Although the reviewer saw improvements during the past year in duplicated efforts, there are still redundancies that should be evaluated to leverage staff most efficiently.

Reviewer 6:

As mentioned previously, it did not seem to this reviewer that there was an opportunity to better focus and integrate the various projects into one cohesive plan. The reviewer observed an overall set of VTO needs/goals and the individual projects, but suggested that a slide demonstrating a sound connection between the two levels would be very helpful. In generating such a slide, the reviewer suspected that duplication may end up being identified, which could be addressed before the next AMR.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:

The realization that energy efficient mobility systems are an important and crucial way to solve the nation’s energy challenges in transportation was described by this reviewer as a key strength of the program. It also seemed that the electric technology and data analytics areas are key strengths. Although conceptual examples should be a strength, the reviewer further commented that conceptual city mobility examples seem to be less focused and a clear understanding of what that program delivers was not communicated.

Reviewer 2:

This reviewer remarked that the overall strategy is complete and can be key in real-world action and solutions. The reviewer further commented that duplication of efforts amongst national laboratories could be reduced and seeking more input from private sector fleet users would give a more complete perspective in modeling and demonstration projects.

Reviewer 3:

The reviewer described good modeling and pulling together data sources as strengths, while lack of development of new data sources as weaknesses.

Reviewer 4:

It was difficult for the reviewer to highlight a project that stands out on either end of the spectrum because the presentation really did not provide an exploration into every single project. The primary strength as seen by this reviewer is that the analyses and projects do appear to be addressing very important questions that have arisen or are likely to reveal themselves in the near future. The weakness is in tying the projects together cohesively, in projecting how exactly these will influence the future, and how the projects weave in all of the safety work and expertise. On the final point, the reviewer explained that there is a risk that a lot of interesting conclusions are generated that all become notably less relevant once safety and/or comfort are factored in later as outputs.

Reviewer 5:

This reviewer referenced Mobility Energy Productivity (MEP) and described it as confusing, though the metric schematic helped to explain it, which is crucial. The reviewer commented that users will not buy into it if it is not explained in a way that users understand. Further, the reviewer exclaimed that this was really helpful; well done.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:

This reviewer pointed out that the e-mobility projects are especially chartering new territory.

Reviewer 2:

The reviewer stated yes and observed that most of the projects result in very appropriate tools being developed for decisions regarding current and future mobility conditions and solutions.

Reviewer 3:
This reviewer indicated a clear yes as the work is formulating.

Reviewer 4:
The reviewer opined that the projects and their approaches do appear to be very innovative and novel, and that they all build on past innovative DOE models that are then tuned and adapted to their particular problem statement. However, the reviewer did think there is room for innovation on the “next steps” front in terms of how to influence the future policy and technology landscape in ways that are not overly intrusive, meet administration/national goals, and are safe/robust.

Reviewer 5:
This reviewer stated maybe, in general, but it was hard to tell from the short presentation.

Reviewer 6:
Nothing really novel was observed by this reviewer, who also noted standard modeling technology.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:
The reviewer commented that most of them do.

Reviewer 2:
This reviewer stated yes, although more private sector engagement would be a benefit.

Reviewer 3:
Broadly speaking, the reviewer reported that engagement is mostly within DOE and their national laboratories as well as universities. There is some initial connection with OEMs and other federal agencies, but more engagement with the private sector and cross-agency would clearly enhance the EEMS program. The reviewer acknowledged that partnering with too many can result in “too many cooks in the kitchen,” but noted there is a happy medium that is not satisfied until more are partners involved.

Reviewer 4:
This reviewer opined that commercial rideshare could play a bigger role, but indicated this is difficult because of competitive reasons. More large-scale service pilots would be helpful.

Reviewer 5:
The reviewer expressed uncertainty regarding this, but it appears that more partnerships are needed and will emerge.

Reviewer 6:
This reviewer did not think the program area engaged appropriate partners because system solutions are being implemented. The reviewer explained that these can and should be elaborate system approaches that deal with a broad variety of government agencies, communities, corporations and policy stakeholders, but did not see that type of discussion.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:
The reviewer replied positively and emphatically asserted that the agency is doing a good job collaborating, for the partners that are defined.

Reviewer 2:
This reviewer remarked that it seems that the program area is collaborating effectively.

Reviewer 3:
The reviewer stated yes and recommended that more with the private fleet sector would be beneficial.

Reviewer 4:
Although this reviewer strongly suspected that the existing partnerships are very robust (mostly universities and within DOE), the presentation did not articulate enough information to judge collaboration effectiveness.

Reviewer 5:
The reviewer expressed that it was difficult to say from the information presented.

Reviewer 6:
This reviewer described it as varying because some of the ELT projects lack clear roles of the collaboration partners. The reviewer further noted concerns with battery supply and being on time.

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:
At this point, the reviewer could see no gaps in the portfolio for this technology area.

Reviewer 2:
The reviewer thought things are on track with the push to expand the Advanced Driver Assistance Systems (ADAS) and connectivity. This reviewer also suggested that having projects look into dynamic charging might be beneficial in the future.

Reviewer 3:
Although there were no portfolio gaps for this technology area that were currently obvious, the reviewer was unsure how Core Evaluation and Simulation and Living Labs really fit into the system. The reviewer explained that systems cannot be tested on benches; real-world piloted projects and examples are needed. Furthermore, this reviewer highlighted the following: Truck Platooning Testing—Transport Canada, PIT; Columbus, Ohio freight tour-based modeling—UPS; Level 4 High Automation (L4) and Level 5 Full Automation (L5) for cars; and the traveler role is really interesting (i.e., EEMS001, EEMS023, EEMS043). The reviewer described collaborating Automated, Connected, Efficient, and Shared (ACES) with the U.S. Department of Transportation (DOT) as very interesting and expressed interest in hearing more because the Program Manager brushed over this a bit too quickly.

Reviewer 4:
This reviewer commented that more effort on collection and curation of good data is needed.

Reviewer 5:
The main gap observed by this reviewer is weaving in safety and comfort into the analyses, which also can come by virtue of enhanced partnering. The risk is that analyzing mostly on the energy side could yield results that are unrealistic when later constrained by safety or comfort considerations.

Reviewer 6:
This reviewer noticed that the main gap is the need to structure system concepts for properly defining the technologies needed to satisfy program goals. Although it would prove very worthwhile, the reviewer acknowledged that it is a difficult task and would take a tremendous analysis effort just to understand how to establish conceptual systems that can make the biggest impact.

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:
This reviewer indicated that no major topics are missing; the technologies that require verification within mobility systems are correct, unless one wishes to consider rail and shipping solutions.

Reviewer 2:
The reviewer did not notice any topics that are being addressed inadequately.

Reviewer 3:
This reviewer did not think there are topics that are inadequately addressed.

Reviewer 4:
Better data collection technology and methodology were recommended by this reviewer.

Reviewer 5:
Mobility of delivered goods within inner cities did not seem to be an area of focus to this reviewer, who opined that it will be a more significant factor in mobility moving forward.

Reviewer 6:
The reviewer referenced prior comments.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:
This reviewer referenced prior comments regarding gaps and expanding partnerships, and reiterated that all of these should be considered for more funding or a shift in funding depending on the project.

Reviewer 2:
The reviewer suggested more focus on infrastructure in terms of vehicle traffic control, dynamic charging, and L5 ADAS.

Reviewer 3:
Satellite imagery for transit data collection was indicated by this reviewer.

Reviewer 4:
This reviewer expressed that greater focus on real-world demonstration projects to conclude, validate, and adjust modeling tools would add value.

Reviewer 5:
The reviewer thought that keeping a focus on last mile is important.

Reviewer 6:
The reviewer referenced prior comments.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:
At this time, the reviewer was unable to recommend new ways to approach the barriers addressed by this program area.

Reviewer 2:
The reviewer stated not at this time.

Reviewer 3:

This reviewer suggested better collaboration (private sector, other agencies, etc.), using existing models outside the DOE when appropriate (universities, other agencies, etc.); and not checking safety at the end of projects, but rather weaving it in as both an input and an output. The reviewer added that there might be redundancy between the various models, approaches, and goals, and that it would be great to show a slide showing the complementary nature of all projects with respect to each other. Further, the reviewer recommended eliminating or thoughtfully identifying projects when redundancies are detected (e.g., the bake-off mentality where the best chef wins).

Reviewer 4:

The reviewer proposed having a structured set of deliverables along with a timeline for every project that outlines targets and objectives, and pointed out that some of the projects lacked that level of detail.

Reviewer 5:

This reviewer recommended developing mobile application platforms that enable new transit services.

Reviewer 6:

The reviewer referenced prior comments and an approach to spend efforts defining what and how to set up the mobility systems that need verification.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:

This reviewer stated no; this is an important program area and perhaps the most difficult one to prepare and define.

Reviewer 2:

The reviewer noted that there was a wide range of ability to communicate amongst the various project presenters, and that it might be worth weighing the possibility of using a deputy or consciously choosing a good communicator for each project rather than defaulting to the Principal Investigator (PI).

Reviewer 3:

This reviewer opined that DOT participation DOT will be beneficial to provide insight on infrastructure and how e-mobility will be a factor on how the transportation portfolio is or needs to be.

Reviewer 4:

The reviewer suggested standards for a national transportation app that enables any transit company to integrate their mobile app routing, scheduling, and payment with real-time flexibility and passenger tracking for autonomous use.

Reviewer 5:

The reviewer was considering this and would provide ideas to the team.

Reviewer 6:

This reviewer referenced prior comments.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0*). In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 3-1—Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
eems001	Energy Impact of Connected and Automated Vehicles (CAVs)	Huei Peng (U. of Michigan)	3-17	3.20	3.20	3.00	3.10	**3.16**
eems007	Mobility Data and Models Informing Smart Cities	Joshua Sperling (NREL)	3-21	3.00	2.67	3.17	2.67	**2.81**
eems009	Modeling and Simulation of Automated Mobility Districts	Venu Garikapati (NREL)	3-25	3.33	3.08	3.25	3.25	**3.19**
eems011	Energy Travel Behavior Modeling in Urban Areas using Behavior, and Autonomy Mobility (BEAM)	Colin Sheppard (LBNL)	3-29	3.30	3.30	3.00	3.00	**3.23**
eems013	Integrated Framework to Quantify the Energy Impact of New Mobility Technologies from Individual Vehicle to Metropolitan Areas	Aymeric Rousseau (ANL)	3-33	3.20	3.40	3.30	3.00	**3.29**
eems016	Energy-Efficient Connected and Automated Vehicles (CAVs)	Dominik Karbowski (ANL)	3-37	3.14	3.21	2.93	2.93	**3.13**
eems017	Impact of Connected and Automated Vehicle (CAV) Technologies on Travel Demand and Energy	Josh Auld (ANL)	3-43	3.07	3.07	3.21	2.86	**3.06**
eems019	Smart Urban Signal Infrastructure and Control	H. M. Abdul Aziz (ORNL)	3-48	3.13	3.38	3.13	2.75	**3.20**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
eems020	Multi-Scenario Assessment of Optimization Opportunities due to Connectivity and Automation	Jackeline Rios-Torres (ORNL)	3-52	3.00	2.83	3.00	2.92	**2.91**
eems023	Whole Traveler Survey on Life Trajectories and Mobility Decisions	Anna Spurlock (LBNL)	3-58	3.10	3.10	3.00	3.00	**3.08**
eems024	Synergy Market Acceptance of Advanced Automotive Technologies (MA3T)—Mobility Choice: Analyzing the Competition, and Adoption of Fuel and Mobility Technologies †	Zhenhong Lin (ORNL)	3-63	3.50	3.33	3.67	3.33	**3.42**
eems026	Expanding Regional Simulations of Connected and Automated Vehicles (CAVs) to the National Level and Assessing Uncertainties	Tom Stephens (ANL)	3-66	3.20	3.10	3.50	2.80	**3.14**
eems027	National Scale Multi-Modal Energy Analysis for Freight †	Kevin Walkowicz (NREL)	3-72	3.63	3.25	3.13	3.50	**3.36**
eems028	Developing an Eco-Cooperative Automated Control System (Eco-CAC)	Hesham Rakha (Virginia Tech)	3-75	3.00	3.08	2.67	3.17	**3.02**
eems029	Boosting Energy Efficiency of Heterogeneous Connected and Automated Vehicle (CAV) Fleets via Anticipative and Cooperative Vehicle Guidance	Ardalan Vahidi (Clemson U.)	3-80	3.29	3.29	3.07	3.36	**3.27**
eems030	Experimental Evaluation of Eco-Driving Strategies	Huadong Meng (Joshua) (LBNL)	3-85	2.67	2.33	2.75	2.25	**2.46**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
eems031	Traffic Micro-Simulation of Energy Impacts of CAV Concepts at Various Market Penetrations	Xiao Yun-Lu- (LBNL)	3-90	2.57	2.64	2.64	2.50	**2.61**
eems032	Evaluating Energy-Efficiency Opportunities from Connected and Automated Vehicle (CAV) Deployments Coupled with Shared Mobility in California	Matthew Barth (UC-Riverside)	3-95	3.25	3.00	3.67	3.33	**3.19**
eems033	Truck Cooperative Adaptive Cruise Control/Platooning Testing: Measuring Energy Savings and Aerodynamic Interactions	Xiao Yun-Lu (LBNL)	3-100	3.40	3.50	3.20	3.10	**3.39**
eems034	Optimization of Intra-City Freight Movement and New Delivery Methods	Amy Moore (ORNL)	3-104	3.30	3.20	3.30	3.00	**3.21**
eems035	Coupling Land-Use Models and Network-Flow Models	Paul Waddell (UC-Berkeley)	3-108	3.50	3.30	3.20	3.10	**3.31**
eems036	Reinforcement Learning-Based Traffic Control to Optimize Energy Usage and Throughput	Tom Karnowski (ORNL)	3-112	3.25	3.00	3.17	3.08	**3.09**
eems037	High-Performance Computing (HPC) and Big Data Solutions for Mobility Design and Planning	Jane Macfarlane (LBNL)	3-117	3.25	3.25	3.25	3.25	**3.25**
eems038	Fuel Selection of Privately Owned Shared Vehicles	Shawn Salisbury (INL)	3-121	3.25	3.38	3.38	3.13	**3.31**
eems039	Commercially Fuel Selection for Fully Automated Owned Taxi Fleet	Timothy Lipman (LBNL)	3-124	3.00	3.00	2.75	2.63	**2.92**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
eems040	Fuel Selection in Automated Mobility Districts/Dynamic Wireless Power Transfer Feasibility	Omer Omar (ORNL)	3-128	2.88	2.88	2.63	2.75	**2.83**
eems041	Hardware-Focused Connected and Automated Vehicle (CAV) Research: Experimental Results and Benefit Analysis	Eric Rask (ANL)	3-132	3.50	3.25	3.17	3.17	**3.29**
eems042	High-Performance Computing (HPC) Enabled Computation of Demand Models at Scale to Predict the Energy Impacts of Emerging Mobility Solutions	Jane Macfarlane (LBNL)	3-136	3.50	3.38	3.38	3.25	**3.39**
eems043	Mobility Behavioral Responses to Transportation Network Company Services	Alejandro Henao (NREL)	3-140	3.00	2.83	3.33	2.67	**2.92**
eems044	Estimation of Potential National Benefits of Advanced Fueling Infrastructure Deployment †	Joann Zhou (ANL)	3-144	3.17	3.50	3.67	3.50	**3.44**
eems045	Focused Validation of Select SMART Simulation Activities †	Erik Rask (ANL)	3-147	2.90	2.90	3.10	2.70	**2.90**
eems046	Understanding Connected and Automated Vehicles in Automated Mobility Districts †	Matt Shirk (Idaho National Laboratory)	3-150	3.30	3.10	3.40	3.40	**3.23**
eems047	An Estimation of Energy Impacts of Various Policies on Personal Travel Model in the San Francisco Bay Area †	Tom Wenzel (LBNL)	3-153	3.13	3.13	2.75	3.00	**3.06**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
eems048	An Analysis of the Spatial Distribution and Impacts of One-Way Car-Sharing Programs on Transit Ridership and Energy Use †	Susan Shaheen (LBNL)	3-156	3.50	3.25	3.50	3.38	**3.36**
eems049	Vehicle Modeling and Data Analysis: Transportation Secure Data Center (TSDC), FleetDNA and FASTSim †	Jeff Gonder (NREL)	3-160	2.88	3.00	2.75	3.00	**2.94**
eems051	SMART Mobility Modeling for Typical Mid-Size City †	Andrew Duvall (NREL)	3-163	3.40	3.30	3.70	3.40	**3.39**
eems052	Resiliency Analysis for Automated Mobility Systems †	Joanne Wendelberger (LANL)	3-168	3.20	3.20	3.20	3.00	**3.18**
eems053	Infrastructure Spatial Sensing at Intersections †	Stan Young (NREL)	3-174	3.13	3.13	3.50	3.25	**3.19**
eems054	Infrastructure Impacts of SMART Technology: Data Analyses on Energy Use †	John Beck (INL)	3-179	2.50	2.50	2.75	2.75	**2.56**
eems055	Simulation Model Results for Energy and Mobility Impact of Behavioral Scenarios in POLARIS †	Josh Auld (ANL)	3-181	3.25	3.25	3.50	3.42	**3.30**
Overall Average				**3.17**	**3.11**	**3.15**	**3.04**	**3.12**

† Denotes a poster presentation.

Presentation Number: eems001
Presentation Title: Energy Impact of Connected and Automated Vehicles (CAVs)
Principal Investigator: Huei Peng (University of Michigan)

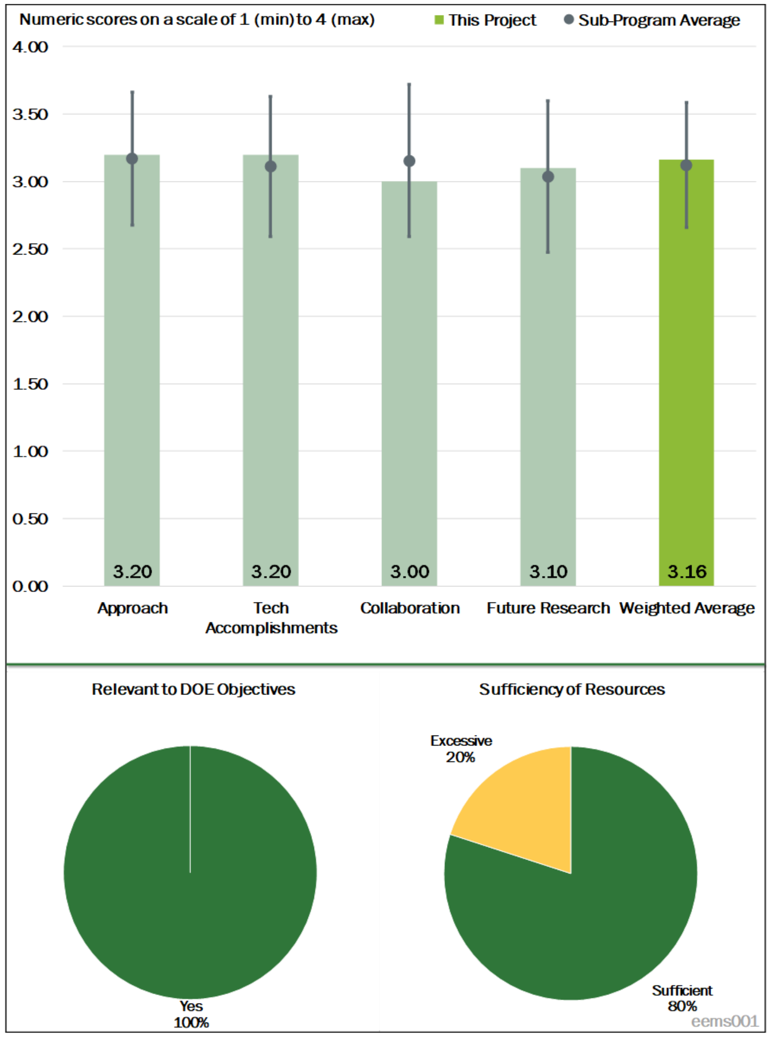

Figure 3-1 - Presentation Number: eems001 Presentation Title: Energy Impact of Connected and Automated Vehicles (CAVs) Principal Investigator: Huei Peng (University of Michigan

Presenter
Huei Peng, University of Michigan

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer remarked that the project really stood out for having taken an excellent approach to developing both models and demonstrating real-world results and data in a robust setting.

Reviewer 2:
The reviewer observed a good timing plan with structure and clear deliverables.

Reviewer 3:
The reviewer acknowledged good plans to address all barriers.

Reviewer 4:
While it is a worthy goal to develop the models required for transportation analysis, and items such as driver behavior are an important aspect, the reviewer did not see the manner in which the 4.5 million miles of data are intended to assist with the model. The reviewer also found unclear what the project intended with the driver behavior model, and questioned whether the goal was to change it or to simulate changing behavior based on certain inputs. Lastly, the reviewer did not see a categorization of drivers listed.

Reviewer 5:
The reviewer stated that the project approach grew less impressive with the completion of each review cycle, and noted that each of the tasks appeared to be scratching the surface of several very large knowledge domains.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that the accomplishments, particularly compared to last year when data were just starting to trickle in, were excellent. The reviewer added that it was clear there was significant depth to the results and findings well beyond the presentation, and that having 4.5 million miles of data is no small accomplishment. The reviewer indicated, however, that some of the accomplishments as presented in the slides were a little thin. For example, Task 2 had an excellent approach using the random forest approach, but a slide on the highlights of what was found and predicted for this task was missing. Nevertheless, other tasks did show interesting results.

Reviewer 2:

The reviewer remarked that work done to date is on target, and suggested having the same driver evaluate different types of cars and comparing economy versus performance to see the difference in behavior.

Reviewer 3:

The reviewer indicated that technical issues have been met for cars.

Reviewer 4:

The reviewer observed that acceptable progress is being made, though it appears that a completion might be difficult with only six months left in the project.

Reviewer 5:

The reviewer is concerned that the most-clearly highlighted technical results were for Task 5 and those results were from a different project (i.e., the China study). The reviewer remarked that the collection of 4.5 million miles of driver behavior data sounded impressive, but inquired about evidence showing return on investment (ROI) for the data collection. The reviewer added that there is not much time left on the project to exploit the data.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said the project has good partners and that they are all relevant.

Reviewer 2:

The reviewer commented that the work done with the University of Michigan is critical to achieving the metrics.

Reviewer 3:

The reviewer observed that all project partners appear to be performing work according to a coordinated schedule.

Reviewer 4:

The reviewer found it unfortunate that partners beyond the national laboratories could not be established.

Reviewer 5:

The reviewer pointed out that the collaboration is missing a private sector representative as well as cross-agency expertise (e.g., National Highway Traffic Safety Administration [NHTSA], Federal Motor Carrier Safety Administration [FMCSA], U.S. Department of Transportation [DOT]). Otherwise, the reviewer added, the collaboration with the two national laboratories and the University of Michigan seems to be very strong.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer asserted that future work looks to be excellent and useful for the U.S. Department of Energy (DOE) in terms of gathering more data, completing or refining several models (including through the use of machine learning approaches), and moving forward with implementing adaptive traffic signal algorithms in Ann Arbor. All of these threads will be valuable and of great interest again at next year's AMR. The reviewer observed that continual improvement is targeted.

Reviewer 2:

The reviewer indicated that future work is logical in that it is a continuation of the previous and current work. The reviewer stated, however, that these efforts are just scratching the surface and appear to be the first—perhaps random—steps in a very long journey.

Reviewer 3:

The reviewer asked where it is possible to include test sites other than Ann Arbor to measure different traffic/driver scenarios and behavior.

Reviewer 4:

The reviewer observed that a few future challenges were listed, but not much time was spent discussing the possibilities.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer acknowledged that the work is highly relevant and becomes more so each year despite being the original EEMS project.

Reviewer 2:

The reviewer is interested in the outcome of the work and its impact on driver behavior.

Reviewer 3:

The reviewer said this level of detail research is needed to move CAV development forward.

Reviewer 4:

The reviewer agreed that the work is moving in a general direction to support DOE's overall objectives, but that it may be some time before these efforts are mature enough to bear significant fruit.

Reviewer 5:

While fundamental research of driver choices and behavior is required, the reviewer saw no effort in this project to categorize the types of drivers or statistically report on these behaviors.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that at over $2 million, there is no doubt that a significant amount of funding has been allocated for this project, though the results speak for themselves. The reviewer observed that it is plausible to reduce funding going forward with robust accomplishments continuing, but that maintaining the funding at this level will enhance the deliverables significantly now that the project has matured to this point.

Reviewer 2:
The reviewer observed no issue with project resources.

Reviewer 3:
The reviewer asserted that the project team has what is needed to complete project.

Reviewer 4:
The reviewer indicated that the ROI for the resource investment on this project was unclear.

Presentation Number: eems007
Presentation Title: Mobility Data and Models Informing Smart Cities
Principal Investigator: Joshua Sperling (National Renewable Energy Laboratory)

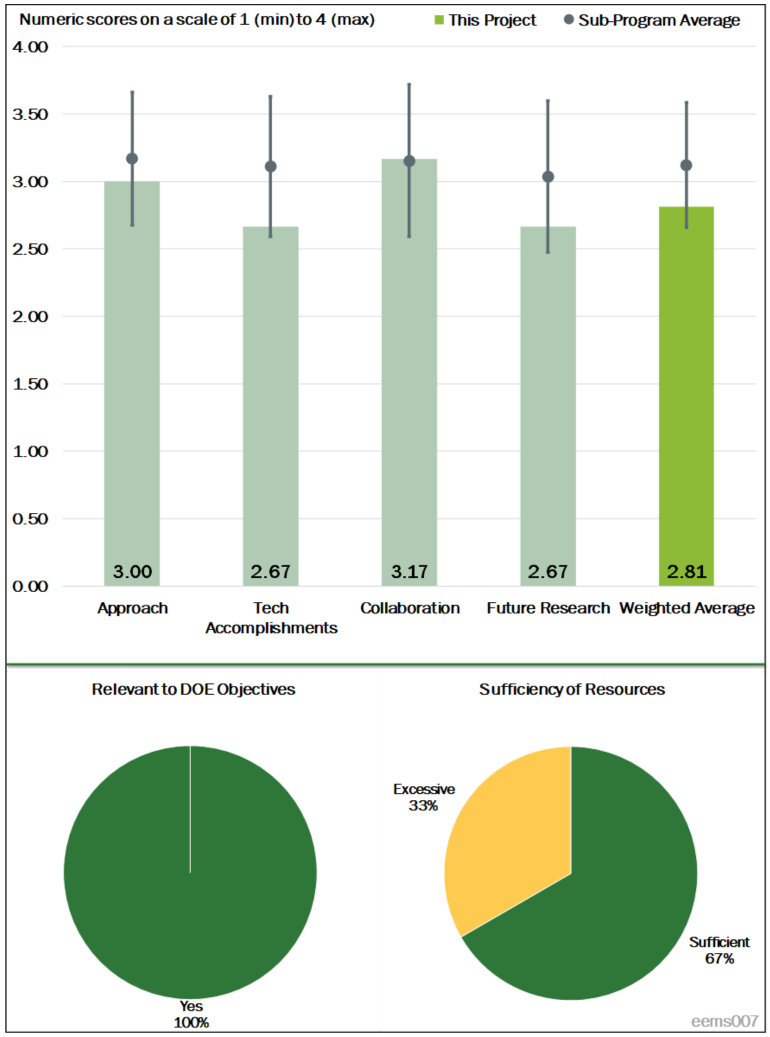

Figure 3-2 - Presentation Number: eems007 Presentation Title: Mobility Data and Models Informing Smart Cities Principal Investigator: Joshua Sperling (National Renewable Energy Laboratory

Presenter

Joshua Sperling, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the project attempts to address key research questions including human behavior, infrastructure, energy, travel, congestion, parking, and land use. The reviewer added that a complete list of research questions was presented, but that the disruptions the technology may impart to any of these areas must be analyzed and understood.

Reviewer 2:

The reviewer commented that the project smartly focused on gathering much-needed data to help the research community answer many important questions on automated, connected, efficient, and shared (ACES) mobility. As such, it has a somewhat unclear set of objectives because the creation and/or gathering of necessary data is highly uncertain. The reviewer expressed appreciation for this challenge, and noted that the direction seems to be good and logical nevertheless.

Reviewer 3:

The reviewer stated that the project purports to focus on data collection, analysis, and utilization for the purpose of better understanding changes in mobility infrastructure and operations. The reviewer indicated, however, that the presentation never made it clear exactly what data were being sought from what sources to probe what questions. The presentation talked about data from Systems and Modeling for Accelerated Research in Transportation (SMART) Cities, but never made clear which cities were involved—saying that there were seven finalists yet only mentioned six cities—or who was collecting what data. The presentation talked about some interesting data from Austin, Texas and Columbus, Ohio, but never made it clear if these data sets were collected in a consistent manner or if they are comparable in any way.

To make a worthwhile contribution to the field, the reviewer noted that the research team needs to do a better job of identifying what very specific questions to answer, what data would provide insight into answering those questions, and then formulate the best approach possible for gathering that data given the constraints imposed by time, funding, and lack of cooperation from participants/subjects. The reviewer indicated that at least a dozen potential sources of data could have been considered and either tried or ignored, but this presentation did not identify any specific sources of data other than vehicle registrations.

The reviewer said the research team needs to identify specific worthwhile questions and then identify potential sources of data that would provide insight or partial answers. As examples, this reviewer inquired about changes in the number of on-road cars at these times in this city over the last 2 years since Transportation Network Companies (TNC) began operating; the number of vehicle miles travelled in that time; the average number of passengers; and how that changed. Sources of data could be car rental companies, TNC, urban transit companies, taxi fleets, airport ground transportation companies, hotels, existing phone applications such as Google Maps and Waze, car dealers or car selling services such as CarMax or Car Gurus, surveys of fleet drivers—either online or paper—or employer-enforced phone company data on location/movement of smart phones, vehicle registrations, oil change records, other research projects, or car manufacturers or leasing companies. Regarding car manufacturers or leasing companies, this reviewer asked whether there is a change in car mileage at the end of their leases.

The reviewer added that if such data are not accessible, then more direct means of collecting data could be considered, such as instrumentation of a subset of all cars or creation of an application that could be downloaded to a subset of drivers to track their movement and number of passengers. All of these have some level of practicality, but the presentation does not make clear what sources of data were considered—other than vehicle registration and SMART Cities sources—or identify what data are needed in what quantity or fidelity to be useful. The reviewer concluded that these issues need to be addressed to have a well-conceived project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the use of the SMART City partners in obtaining data on urban models is particularly insightful. The reviewer added that the analysis will be favorable to future decisions despite being challenging due to lead/lag enablers.

Reviewer 2:

As the project is a bit unclear on its exact roadmap for collecting and cataloging its data, the reviewer found it hard to objectively measure progress. The reviewer expressed that, subjectively, there appear to be many reasonable steps and choices. The reviewer added that, given how little data on ACES exist in the public domain, or even under non-disclosure agreements (NDAs), it is understandable that the project is casting a wide net. The reviewer stated that it would also be helpful to have a clearer documentation of failures, such as, “We tried to gather this, but ran into these roadblocks.” This would, in many cases, help the research community understand what has been done and avoid duplication of this project’s efforts.

Reviewer 3:

The reviewer could not tell how much progress has been made or what kind of progress it has been, adding that while the presentation included several slides that used the words “Technical Accomplishments,” the project team was unclear about specific accomplishments. The reviewer could not tell if the slides were just repeating data and conclusions from other prior studies, or if they were presenting new results and conclusions. The reviewer noted that the slides were a collection of differing formats and contents, some with bullet points and incomplete thoughts while others had long paragraphs that seemed to describe problems and not accomplishments. The reviewer added that other slides had tables that are virtually incomprehensible. The reviewer stated that while the team has analyzed something and identified some trends or changes, such as those summarized on Slide 16, there is no consistent summary of accomplishments towards any clearly defined goals.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the project collaboration brings together excellent skills and data potential, particularly with the SMART City partners.

Reviewer 2:

The reviewer expressed that the team appears to have been very successful in identifying and networking with those that do have data and are willing to share. The reviewer commended attempts to come up with a common set of metrics across metro areas.

Reviewer 3:

The reviewer stated that there appears to be some collaboration between team members simply because some slides refer to different members of the team, but that the presentation never makes clear who is supposed to being doing what for what reason. The reviewer noted that, based on the presentation, all team members are vaguely defined and seem to be doing exactly the same thing for the same reasons. The reviewer concluded that the roles of the different team members need to be defined (i.e., identify who is doing what and why).

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer observed that future work described in this project appears to be focused on achieving the stated objectives of the project, adding that data will be necessary to advance the predictive or decision-making capabilities.

Reviewer 2:

The reviewer expressed that the general direction of the project is good despite the understandable lack of certainty in that certain data can be collected and synthesized. In addition to collecting data from partnerships with various metro areas, the reviewer encouraged the team to think deeply about how to create additional data, especially on the usage of TNC vehicles. The RideAustin data are valuable, but it is just one metro area for one period of time. While Uber and Lyft may not want to share data, there are other TNCs that may be more willing to share (or sell) their data.

Reviewer 3:

The reviewer indicated that the plan for the future, as stated in the presentation, revolves around data, yet only a vague description of the potential sources of that data are provided. The reviewer added that the phrases "upscaling urban data integration" and "new emerging data and models" tell the observer almost nothing, adding that this is not surprising given that the presentation never defines what data are required nor how they might be collected. As a result, the reviewer observed, the future plans are very general.

The reviewer also remarked that the research questions posed on Slide 20 are all much too vague and high-level to be of value. The questions must be much more specific to provide guidance for the future, and there are no decision points or thoughts about mitigating risks because there is no clear path that this work is following. The reviewer affirmed that the project team is trying to do something useful with limited inputs, but that the team needs to do a better job of defining where the project is going and why. Once this is defined, the project plan will describe how to get there. The reviewer warned that none of that seems to exist in any concise form at the moment.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer asserted that DOE objectives are clearly being met by sponsoring this analytical project.

Reviewer 2:

The reviewer noted that a clear lack of data remains one of the biggest issues for EEMS, and that this project is taking that challenge on directly. If successful, the reviewer added, the project will help other EEMS groups working narrower projects.

Reviewer 3:

The reviewer stated that DOE has an objective of better understanding SMART mobility and assessing how it will impact energy use and infrastructure requirements in the future. The reviewer commented that the project might help provide insights toward that objective if it were better planned and executed. Although the project is operating in the right topic area to support DOE's objectives, this reviewer emphasized that it is currently doing very poorly because the research plan is deficient.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that this project appears well funded for successful completion.

Reviewer 2:

The reviewer expressed that it is hard to know how and where the money is being spent as no specific budget was included. The reviewer noted that, nevertheless, purchasing or creating data needs to be considered even if this meant an increase in budget.

Reviewer 3:

The reviewer noted that the appropriateness of the resources and their allocation on this project are not clear. While Slide 2 indicates an overall project funding of $1.65 million, the slide states that funding in Fiscal Year (FY) 2017 and FY 2018 is only $220,000. The reviewer thus questioned where the rest of the funding is going, whether it has been spent already or being held for 2019, or whether it is being spent by other team members.

Based on the muddled work plan, the reviewer believed that the funding is not being put to good use and that the fact that the roles for the different team members are not clearly defined reinforces this. The reviewer remarked that a budget of $1.65 million should be sufficient to do some interesting things from a data collection standpoint, such as generating surveys, developing applications, paying drivers to collect data, paying private companies for data, or even instrumenting a subset of vehicles with data collection devices. The work plan mentions none of these techniques, making an observer believe that the project team is hoping to obtain data collected by someone else and then evaluate it to see what it might say. The reviewer warned that this approach may be inadequate and, unless the project team can devise a better plan, the resources devoted to this are excessive.

Presentation Number: eems009
Presentation Title: Modeling and Simulation of Automated Mobility Districts
Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory)

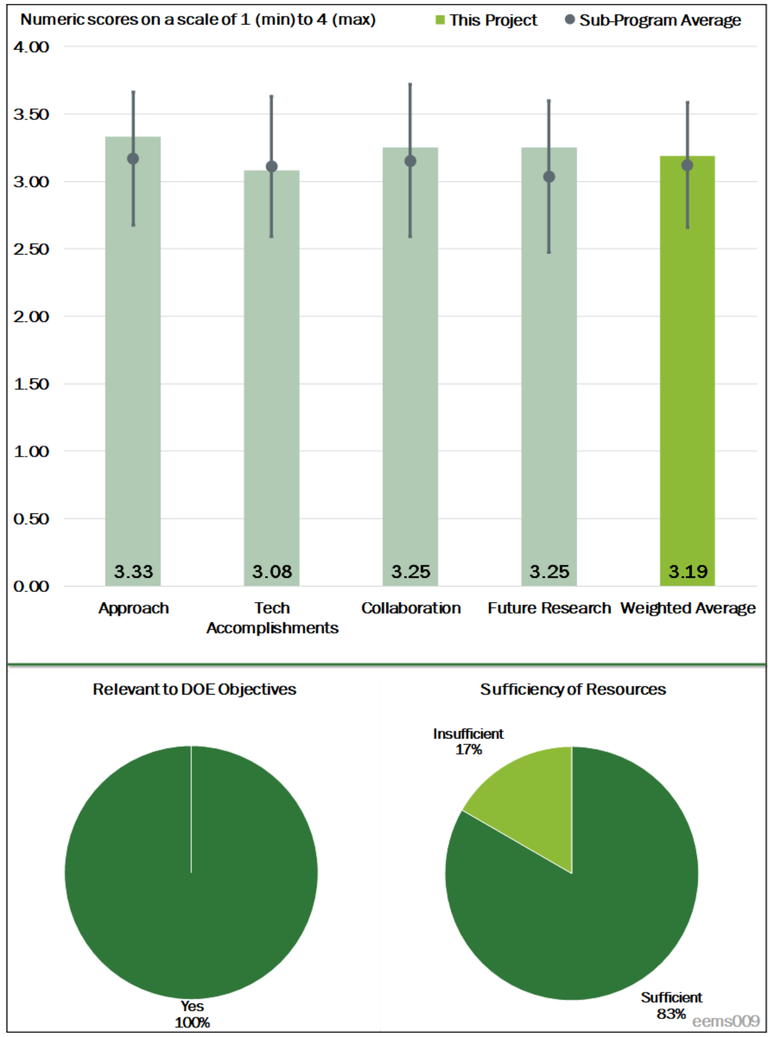

Figure 3-3 - Presentation Number: eems009 Presentation Title: Modeling and Simulation of Automated Mobility Districts Principal Investigator: Venu Garikapati (National Renewable Energy Laboratory)

Presenter
Venu Garikapati, National Renewable Energy Laboratory

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer noted that the approach is good for a complicated task.

Reviewer 2:
The reviewer observed that the approach to studying and evaluating Automated Mobility Districts (AMD) by the detailed study of one such area is compelling. The reviewer believes that this more limited analysis—as opposed to some very large-scale, all-inclusive models—will give accurate insight to the benefits of an AMD during these developmental periods of time.

Reviewer 3:
The reviewer remarked that the approach seems aligned with how municipal entities can utilize the modelling capability.

Reviewer 4:
The reviewer stated that the overall design of the study is well-focused and does a good job at addressing the questions at hand. The reviewer looks forward to more detailed results in the coming year.

Reviewer 5:
The reviewer remarked that the approach and objectives are well laid out, clear, and focused.

Reviewer 6:
The reviewer found it unclear how preliminary AMD simulation is correlated to real-world AMD and whether the results from the simulations provide value. The limited size of the automated electric shuttles (AES) fleet may make it difficult to correlate the effect of the AES on the AMD. Because customer awareness and

acceptance are large factors to the usage behavior, the reviewer recommended providing an overview of the initiatives in these areas.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer observed good accomplishments so far.

Reviewer 2:
The reviewer did not have any serious concerns thus far, and noted that the amount of output appears to be on track with the plan.

Reviewer 3:
The reviewer indicated that progress appears to be good, but suggested it may have been better with greater, earlier cooperation of Greenville model boundaries (appears to be commonly confronted Memorandum of Understanding [MOU] negotiations). The reviewer noted that human choice behaviors do not appear to be analyzed in the project, adding that as difficult as they are to predict, the human element is the most variable to the transportation efficiency.

Reviewer 4:
The reviewer reported good progress. Regarding the mode share, the reviewer questioned which assumptions were used to create the third scenario, and asked whether a similar mode shift from TNCs was assumed.

Reviewer 5:
The reviewer found unclear how relevant the preliminary AMD simulation results are. The reviewer observed that a relationship between the transition from walking to automated shuttle use and the corresponding change in vehicle average travel time (VATT)—including walking—seems integral to the quantification of net mobility, yet it has not been demonstrated. The reviewer added that fuel consumption should include an equivalent value for electricity consumed to power the AES vehicles.

Reviewer 6:
The reviewer stated that progress was a bit difficult to evaluate with the information provided, but that it looks good overall.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that a good team was assembled.

Reviewer 2:
The reviewer commented that the addition of these transportation districts since last year will bring added benefit to the analysis. The reviewer remarked that the SMART Mobility Laboratory Consortium is an extremely talented base of collaborators, and is almost assured of a successful completion to this project.

Reviewer 3:
The reviewer commended collaboration across military, education, cities, and government laboratories.

Reviewer 4:
The reviewer expressed no concerns with the project team, and applauded the interaction with Greenville. The reviewer stated that Slide 9 mentions Austin, but that no further details were provided and it is unclear whether that was a mistake in the slides.

Reviewer 5:
The reviewer suggested the project team collaborate with the Federal Transit Administration for any nexus with their research on automated buses and shuttles. The reviewer questioned whether the project team had coordinated with other transit agencies that are attempting to pilot automated shuttles.

Reviewer 6:
The reviewer stated that the extent or effectiveness of collaborations was not possible to determine from the slides presented. For example, the reviewer was not able to determine what data are being provided by City of Greenville, how do those data fit into the simulations, and how data privacy is being addressed.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer asserted that future research and developments will be very valuable.

Reviewer 2:
The reviewer stated that the proof of the techniques' effectiveness will be assessed in the Greenville study, and that, if successful and valuable, the expanded use of this analysis could be used for broader analysis as planned.

Reviewer 3:
The reviewer expressed that accomplishing the proposed future research would be essential to demonstrating some value of the research done thus far, adding that the proposed research looks appropriate and impactful.

Reviewer 4:
The reviewer indicated the plan looks good and that the next phase is when the project starts getting interesting results. Although perhaps beyond this project's scope, this reviewer suggested some discussion of how this AMD modeling might be extended over larger geographies in the future.

Reviewer 5:
The reviewer affirmed that the FY 2019 work provides a good focus on applicability and usability of the product.

Reviewer 6:
The reviewer commented that the integration of the Future Automotive Systems Technology Simulator (FASTSim) to perform energy analysis is not clear. The reviewer added that fulfilling the main project objective of quantifying energy impacts of ACES deployed in dense urban districts requires greater analysis than indicated.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer observed that, once applied, the project will save fuel and reduce congestion.

Reviewer 2:
The reviewer noted that, similar to other EEMS programs, the analysis is essential for studying and identifying areas for public policy needed to reduce energy use and provide the public with clean and efficient mobility options.

Reviewer 3:

The reviewer commented that it seems plausible that the earlier, real-world, highly automated mobility-as-a-service (MaaS) would occur in a limited campus or district. These modeling tools could then be used to check against a ground truth that actually exists. The reviewer added that further thought should go into broadening the AMD work to larger geographies, though that may be out of scope for the current project.

Reviewer 4:

The reviewer noted that there is a clear connection to energy consumption.

Reviewer 5:

The reviewer stated that the project supports overall DOE objectives by developing modeling capabilities to estimate impact of AMDs.

Reviewer 6:

The reviewer observed that the project objectives are a restatement of the overall DOE objectives for this program.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer warned that resources appear to be insufficient to cover the large scope in determining impact of AMDs, and that with larger funding more sites could be explored and modeling correlation could be more robust.

Reviewer 2:

The reviewer affirmed that the project has sufficient resources.

Reviewer 3:

The reviewer stated that resources are in line with what is required for this type of effort.

Reviewer 4:

The reviewer observed that no detailed budget was provided, but that overall budget appears reasonable for the scope of the project.

Reviewer 5:

The reviewer remarked that nothing in the presentation indicated anything other than sufficient resources.

Reviewer 6:

The reviewer expressed difficulty in assessing resources needed for the project, and added that no mention of deficiencies were presented nor explained.

Presentation Number: eems011
Presentation Title: Travel Behavior Modeling in Urban Areas using Behavior, Energy, Autonomy, and Mobility (BEAM)
Principal Investigator: Colin Sheppard (Lawrence Berkeley National Laboratory)

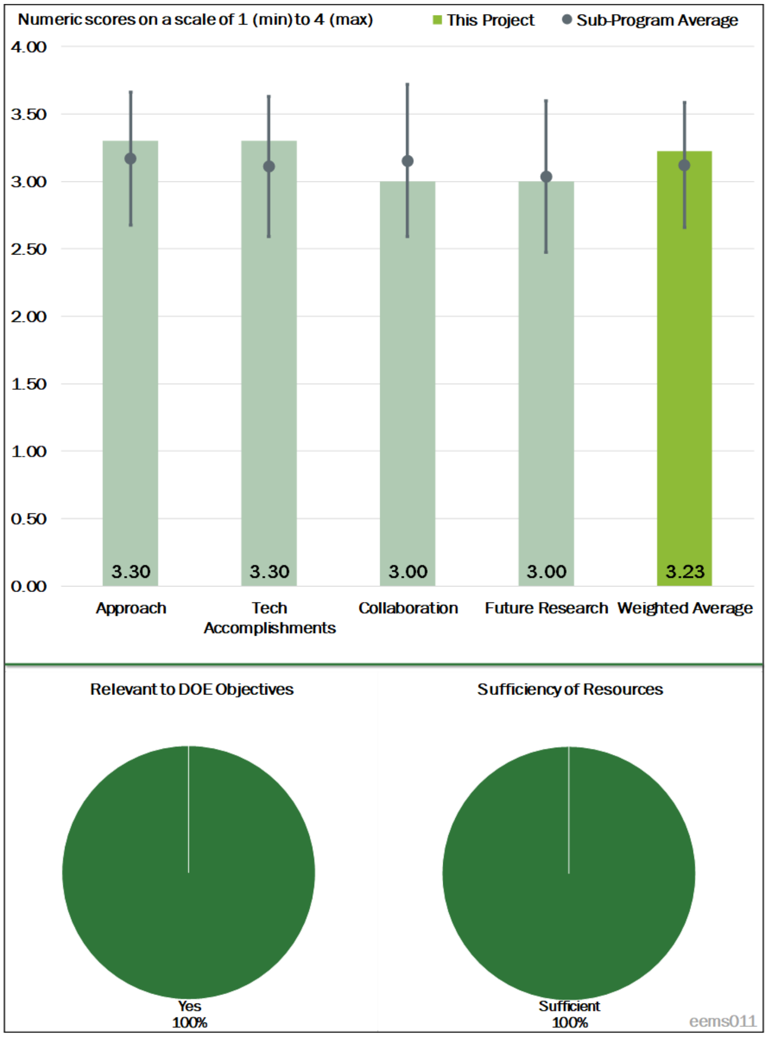

Figure 3-4 - Presentation Number: eems011 Presentation Title: Travel Behavior Modeling in Urban Areas using Behavior, Energy, Autonomy, and Mobility (BEAM) Principal Investigator: Colin Sheppard (Lawrence Berkeley National Laboratory)

Presenter

Colin Sheppard, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that this is a challenging multi-discipline project, and expressed that the approach of enhancing the model, validating it, and then conducting analysis seems solid.

Reviewer 2:

The reviewer noted that this is a highly skilled effort to simulate multiple variable transportation mode selection and optimization for energy efficiency. The models being developed, though analyzing energy use, must attempt to project scalable future decisions (i.e., behaviors) of users (i.e., agents) in a changing environment of needs and choices.

Reviewer 3:

The reviewer stated that, overall, this is a rational, measured approach focused on incremental improvements to models. The reviewer commented that the transportation system is becoming more complex, and this project is attempting to reflect—and thus model—this more effectively in order to obtain energy consumption and other impacts. The reviewer said that the only concern might be that, given that this project is focused on addressing an increasingly complex area, there could be an argument made for a continuous, on-going project long beyond the currently-identified schedule.

Reviewer 4:

The reviewer remarked that the focus on incorporating behavioral insights in modeling is valuable, but pointed out that the reliability of validation and other methodological elements is unclear given the qualitative differences between existing and emerging mobility options. The reviewer concluded that the treatment of the value of time looks simplistic as it does not appear to reflect the ability to be productive in transit.

Reviewer 5:

The reviewer observed that the project aims to endogenize traveler behavior in Behavior, Energy, Autonomy, and Mobility (BEAM)—a fully multimodal and scalable urban simulation tool—to understand the impact of behavior on regional energy outcomes. The reviewer added that the project will enable a full range of multimodal travel decision making in agent-based transportation system models. The reviewer stated that the project is intended to continue to develop BEAM, but there is no listing presented of the individual travel decisions that are included in the previous model development. Therefore, while the approach may be technically able to progress, there is no way to determine whether the approach has included the necessary current and future modes of travel since only those elements to be added are listed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the project appears to be on schedule and has made significant progress towards its goals and addressing its barriers.

Reviewer 2:

The reviewer asserted that the project has an excellent assembly of resource markets to simulate behavioral transportation behavior, and that considerable variable input boundaries have been included for meaningful analysis.

Reviewer 3:

The reviewer commented that technical accomplishments are significant and consistent with project objectives.

Reviewer 4:

The reviewer observed that, over the past year, a number of modules have been added to attempt to reflect more elements of the overall picture, particularly more recent items like ride-hailing. In particular, the team added necessary constraints to the system in the areas of road/vehicle capacity, parking/refueling access, and TNC capacity.

Reviewer 5:

With respect to Slide 8, the reviewer pointed out that the project is adding many new elements to BEAM. The reviewer stated that the full features model will happen later in 2018, but that only what has been added was reported and instead of the full features that will be available. The reviewer questioned whether it was assumed that reviewers were all intimately familiar with BEAM, adding that it should have showed both what was already there and what is to be added in order to evaluate if it would truly be a full-featured system at year end.

Regarding Slide 9 and BEAM, the reviewer asked how this product would be used and by whom, saying that it seems to be a tool for academic use and not one useful for transport planners. The reviewer said that the project is too math-oriented and very academic, leaving uncertainties as to how it would be used in the real world.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that coordination with team members, as well as with related research EEMS017, was clear.

Reviewer 2:

The reviewer said that while the presentation did not elaborate on the exact contributions of each team, based on both the progress and skill sets it appears that the teams are collaborating very well.

Reviewer 3:

The reviewer observed that there seems to be good collaboration between the project members. The reviewer believed input from local city representatives for San Francisco, Chicago and DOT would be valuable. It was not clear to the reviewer whether the team had looked into that collaboration or coordination, if even it was just to get feedback on the results thus far.

Reviewer 4:

The reviewer acknowledged that the project team, led by Lawrence Berkeley National Laboratory (LBNL), also includes other involved laboratories, a university, and an industry partner who supports local planners. The reviewer offered that it might have been interesting to have included a local government or two in order to provide a stronger and more direct link to real-world data and issues, as well as smoothing the path to implementation.

Reviewer 5:

The reviewer indicated that there are only internal collaborations and no collaborators outside of DOE. The reviewer stated that this is a transportation modeling tool, and asked where the inputs of the transportation planners and providers of transportation services are in order to bring reality to the tool.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer believed the future research is within the project scope and milestones, and affirmed that the project will focus on San Francisco and Chicago. The reviewer expressed that it would be good to understand how effective the model would be for other cities with different population densities.

Reviewer 2:

The reviewer stated that the FY 2019 work shown in the presentation described a logical progression of the project.

Reviewer 3:

The reviewer noted that future incorporation of Whole Traveler results and multiple impact assessments looks reasonable.

Reviewer 4:

The reviewer stated that, overall, the proposed future efforts seem to make sense and are focused on incremental improvements and additions to the model. The reviewer found the calibration and validation of particular interest, as they will determine the ultimate accuracy of the model. Because these efforts have only begun, the reviewer was unclear on how effectively these functions will be completed. The reviewer was also unclear on the periods of time (i.e., duration span of the data) that will be used to ensure accuracy.

Reviewer 5:

The reviewer remarked that, without collaborations outside of the national laboratories and academic circles, the future research will make the end-product only marginal in applicability. The reviewer questioned when the user community would join this project.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer stated that all EEMS projects address reduced petroleum dependence.

Reviewer 2:
The reviewer noted that the project is focused on improving models for determining energy consumption impacts based upon transportation implementation, including both technologies and behavior. The reviewer commented that the hope would be that, once calibrated and validated, such models could be used to determine the energy impacts of different policies, technologies, or behaviors introduced into implementation.

Reviewer 3:
The reviewer indicated that the models must provide insight on future transportation decisions, which will greatly affect the transportation efficiency and thus energy efficiency of society.

Reviewer 4:
The reviewer affirmed that the project supports DOE's objective of petroleum consumption reduction and EEMS's objective of decoupling mobility from energy use.

Reviewer 5:
The reviewer agreed that the subject matter is relevant, but remarked that the approach and lack of collaborations makes it marginally useful in the real world. In that light, the reviewer affirmed that the question of whether the project is a good investment looms.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that, based on the project's progress with the funding provided, project resources seem to be sufficient.

Reviewer 2:
The reviewer noted that the resources look reasonable.

Reviewer 3:
The reviewer said the resources appear sufficient for now. The reviewer questioned whether this project's efforts are more of a continuous nature and would thus go on past the currently-identified schedule, requiring additional resources.

Reviewer 4:
The reviewer indicated that, although resources were not elaborated upon during the presentation, it appears that there is significant progress at the allocated budget.

Reviewer 5:
The reviewer expressed difficulty in stating whether resources are sufficient when the outcome appears to be flawed. The reviewer stated that the problems are due to lack of a good plan that needed broader collaborative partners, and suggested the program office assess whether this is a lack of resources or simply bad planning.

Presentation Number: eems013
Presentation Title: Integrated Framework to Quantify the Energy Impact of New Mobility Technologies from Individual Vehicle to Metropolitan Areas
Principal Investigator: Aymeric Rousseau (Argonne National Laboratory)

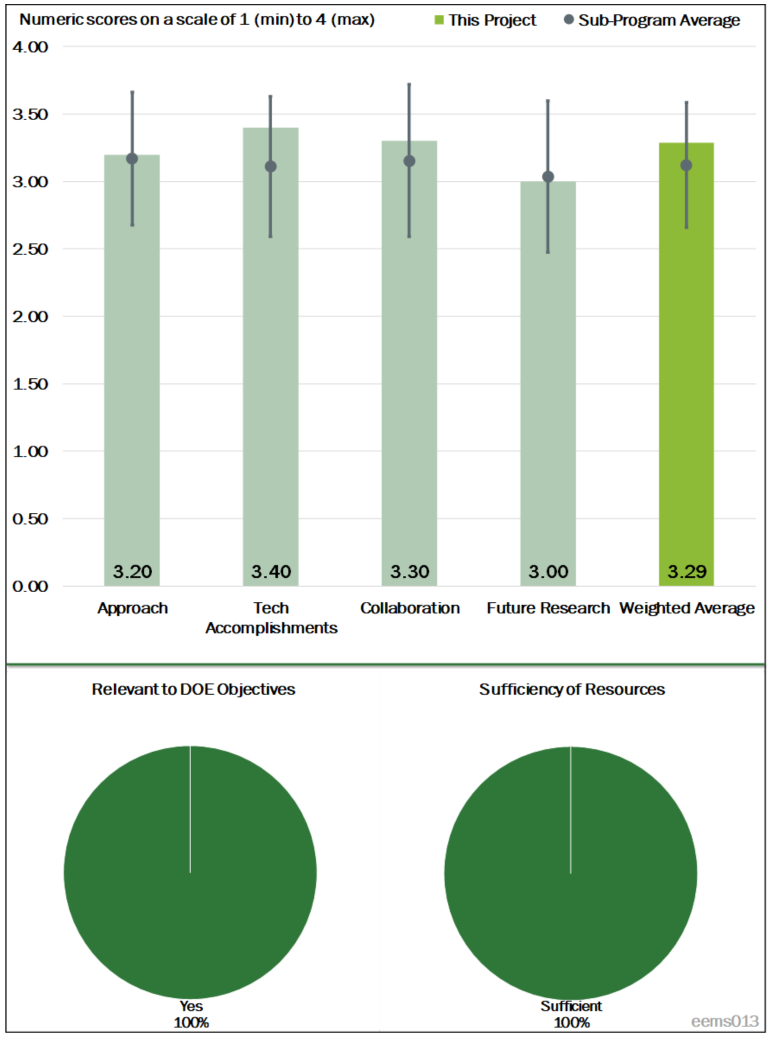

Figure 3-5 - Presentation Number: eems013 Presentation Title: Integrated Framework to Quantify the Energy Impact of New Mobility Technologies from Individual Vehicle to Metropolitan Areas Principal Investigator: Aymeric Rousseau (Argonne National Laboratory)

Presenter

Aymeric Rousseau, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said the project seems like an interesting integration of analysis tools.

Reviewer 2:

The reviewer stated that the project continues to expand the capabilities of the simulation tool suite in a comprehensive manner and noted that the features added are highly relevant to DOE’s Vehicle Technologies Office (VTO) projects and improve analytical capabilities.

Reviewer 3:

The reviewer liked that that the project team is progressing the tools, but noted that it was a very generalized presentation.

Reviewer 4:

The reviewer acknowledged that the project team developed the Advanced Model Based Engineering Resource (AMBER) workflow manager—a new transportation system level simulation tool developed by Argonne National Laboratory (ANL)—that includes: Autonomie, a vehicle level simulation based on powertrain; RoadRunner, a multi-vehicle corridor travel simulation; Stochastic Vehicle Trip (SVTrip), a commercial tool; and the Planning and Operations Language for Agent-based Regional Integrated Simulation (POLARIS), a DOT agent-based transportation network system.

Reviewer 5:
The reviewer stated that the approach is overall good as integrating models will be essential to answering system-wide questions. The big missing piece is on demand, where many of the most important effects to model will be. The reviewer understood that this is not necessarily in scope now, but noted that the approach needs to include efforts to make it easy to integrate with demand models that are being developed in the future, and represent important feedback such as cost and time of travel.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer remarked that impressive progress and important technical work have been achieved, primarily as tool development to support novel research.

Reviewer 2:
The reviewer indicated that the project is on track, and that progress on enhancing POLARIS is impressive.

Reviewer 3:
The reviewer affirmed that the project team developed vehicle models for the latest technologies (more than 125 xEVs by analyzing powertrain by OEM) and significantly expanded medium- and heavy-duty vehicle model capabilities (13 vehicle classes representing more than 50% of the U.S. truck population and a large number of test cycles). The main studies developed include Advanced Combustion Engine targets updates, Co-Optima benefits quantification, and real-world fuel economy predictions. This reviewer further observed updated RoadRunner process automation, expanded POLARIS capabilities (to share study results with research community), and migration to Linux for HPC.

Reviewer 4:
The reviewer would have found it useful knowing what the project team actually spent its money on, and reported that it is just a large number—$4.5 million over FY 2015-2018. The reviewer asked whether the project team accomplished all of its goals, whether everything went as planned, and if there were any issues.

Reviewer 5:
The reviewer found it hard to assess the technical accomplishment and progress from this presentation, adding that the presenter went through the material too quickly and was unable to finish in time.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that there are many users and a strong consortium.

Reviewer 2:
The reviewer noted an impressive number of collaborative organizations, and indicated that the necessary linkages for tool design input are in place.

Reviewer 3:
The reviewer observed numerous users from government, industry, and academia supporting a number of DOE programs, including VTO program areas, the Advanced Research Projects Agency-Energy (ARPA-E), and the corporate average fuel economy (CAFE). The reviewer added that there are various university, DOE national laboratories, and government agency partner collaborations.

Reviewer 4:
The reviewer would have liked to see a responsibility assignment chart showing what each partner actually did. The reviewer would have also liked to know whether users were interviewed and what their concerns were, how much money was spent with outside companies, and what the team's expected budget going forward is.

Reviewer 5:
The reviewer indicated that only a list of many companies was provided without details.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the project is 95% complete (started in FY 2015 and ended in September 2018), and the proposed future research is to continue to develop and apply tools to estimate mobility and energy impact of new technologies in support of EEMS programs. The reviewer added that specific topics include traveler decisions, building energy, charging network and usage, new mobility services, and metropolitan areas.

Reviewer 2:
The reviewer noted that the project is nearly complete, but should include some plan for integrating with models that can represent travel behavior.

Reviewer 3:
The reviewer indicated that the proposed future research description is generally good, but could be improved with more specific goals and tasks.

Reviewer 4:
The reviewer asked exactly what the project team is looking at to support EEMS activities. The reviewer would have liked more planning what is expected next. The reviewer would have also found it helpful to show what vehicles and powertrains were modeled, and whether any proposed new powertrain combinations will be modeled.

Reviewer 5:
The reviewer strongly declared that the presenter ran out of time.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said the project is a good development of analysis tools and models.

Reviewer 2:
The reviewer commented that this a core project on DOE EEMS goals.

Reviewer 3:
The reviewer affirmed the project's tools are critical for energy analysis of DOE projects exploring technologies or policies to reduce energy consumption.

Reviewer 4:
The reviewer stated that the project simulation tools and results support a number of VTO projects as well as organizations throughout the world to define research and development (R&D) targets, evaluate the benefits of advanced technologies, and provide R&D guidance which all contributes to DOE objectives of reducing petroleum use and dependence to increase U.S. energy security.

Reviewer 5:
The reviewer loved all of this modeling and simulation for supporting DOE objectives, including “what if” powertrains in the future. However, the reviewer did not see that in this project. The reviewer asked if the project team is planning to do that, and what technologies, battery efficiencies, and break-throughs would need to be in play to do this. The reviewer further inquired about how much it would take to do the R&D for these breakthroughs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer indicated that resources seem sufficient.

Reviewer 2:
The reviewer stated that $1.5 million in FY 2018 funding and $4.5 million from FY 2015 to FY 2018 seem appropriate given the wide breadth of simulation tools that this project supports and connects in the new AMBER simulation tool framework.

Reviewer 3:
The reviewer noted that the budget allocation has been steady and the proposed work is being completed within the assigned resources.

Reviewer 4:
The reviewer could not tell from the presentation if the project team’s resources were sufficient or not. The reviewer asked what the project team really accomplished versus its goals, and what was not accomplished. The reviewer concluded that a good self-assessment was lacking here and cannot be assessed by a reviewer.

Reviewer 5:
The reviewer assumed that resources were sufficient, as it was not brought up in the presentation.

Presentation Number: eems016
Presentation Title: Energy-Efficient Connected and Automated Vehicles (CAVs)
Principal Investigator: Dominik Karbowski (Argonne National Laboratory)

Presenter

Dominik Karbowski, Argonne National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

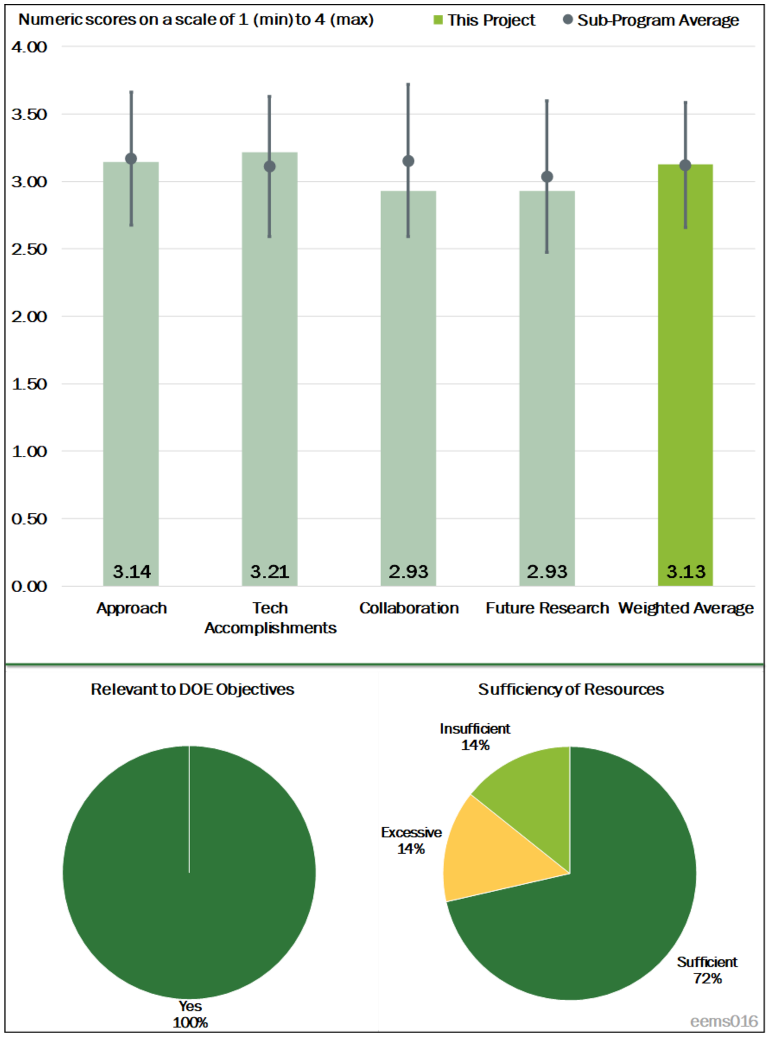

Figure 3-6 - Presentation Number: eems016 Presentation Title: Energy-Efficient Connected and Automated Vehicles (CAVs) Principal Investigator: Dominik Karbowski (Argonne National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed that modeling tools being developed are appropriate to the task. The reviewer said the RoadRunner solution is a good approach to tackling the simulation requirements, and suggested making it more flexible so that it can be more easily adapted to other vehicle simulation tools. The reviewer also commented that the theoretical optimization study is useful to obtain upper bound on benefits attainable with eco-routing.

Reviewer 2:

The reviewer said the research is well thought out and progressive. The reviewer observed that the approach focused on eco-driving research for optimal and predictive CAV speed and powertrain control for best fuel efficiency, and on the development of a multi-CAV simulation framework (i.e., RoadRunner) for varying powertrain and traffic scenarios. The reviewer remarked that the approach utilizes existing tools like the Autonomie model, and ties with data and work others are producing in the area. The reviewer noted that the research team plans to eventually release RoadRunner to the public as a CAV research tool.

Reviewer 3:

The reviewer would like to see a comparison between POLARIS and RoadRunner and the value that each of these approaches brings to estimating energy savings for connected and automated vehicles (CAV). The reviewer inquired as to why both tools are needed, and observed that both tools seem to use Automonie as a calculating engine for fuel use.

Reviewer 4:
The reviewer stated that the project is well scoped and methodological for addressing the technical barriers. The reviewer suggested that further improvements would be to comprehend the sensitivity of dynamic speed control and the acceptance by passengers and impacted human drivers of surrounding vehicles.

Reviewer 5:
The reviewer remarked that this is an interesting project that fits well in the overall theme of the SMART Mobility Consortium, though the approach taken is rather confusing. The reviewer was not clear on why both an offline (i.e., optimization) and online (i.e., model predictive control [MOC]) framework had been used.

The reviewer was also confused as to why the principal investigators (PIs) developed a car-following model at a time when there are so many well-documented models available in the literature, e.g., Gibbs, Widemann. The reviewer inquired as to how the proposed car-following model is different from the aforementioned ones, how the RoadRunner is associated with the vehicle controller, and which assumptions were used.

Reviewer 6:
The reviewer stated that, at a macro level, the work covered important factors, though it was unclear how large the simulated system is. The reviewer commented that, while it is reasonable to start with a limited number of vehicles and limit complexity, there remains a need to understand the limits of this output and structure a pathway to model complexity of systems with orders of magnitude more vehicles.

Reviewer 7:
The reviewer observed that the project is trying to improve an existing analysis tool, RoadRunner, and that the overall intent was stated as having a system that may be incorporated in salable vehicles. The reviewer noted that there are many more parameters that need to be included before any established vehicle company would even consider using the control system.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer observed that progress seems to be excellent, with the stated sub-goals substantially completed on time.

Reviewer 2:
The reviewer appreciated the approach shown on Slides 6 and 7 to address the situations that are trying to be proven. The reviewer found the 3%-7% shown on Slide 17 reasonable when balancing all drive cycles together. For stating CAV potential savings, the reviewer prefers this approach over stating large fuel economy improvements for very specific situations. The reviewer did not see accessory load assumptions listed in the material.

Reviewer 3:
The reviewer observed that the researcher indicated the project was 40% complete as of the AMR, which appears to be a little behind schedule for a three-year project that started in October 2016. The reviewer noted that FY 2018 accomplishments included completion of a closed loop eco-driving controller with predictive control, as well as case study development of eco-driving strategy energy impacts for conventional and hybrid electric vehicle (HEV) powertrains and further development of the RoadRunner framework, including validation and case studies. The reviewer further noted that framework development efforts include further integration with Automonie algorithms and collaboration with HERE for roadway route data and updating human driver models. The reviewer also noted that research implemented model-predictive control (MPC) in RoadRunner as a first step to next year’s work.

Reviewer 4:
The reviewer indicated that progress is very good, and that it would be helpful to understand the assumptions underlying the baseline human driver and what data/research were used in developing the driver models. The reviewer said that in-use driving is much different than driver models developed for certification testing, and suggested that the additional mass, aero-, and electrical load increases be quantified and compared to the benefits for each type of automated driving system.

Reviewer 5:
The reviewer stated that, while the PIs have made progress to date, it was not quite clear from the presentation where the benefits come from, e.g., powertrain optimization, speed profile optimization. The reviewer suggested the PIs create a table and list the benefits against the powertrain optimization or CAV applications, among others.

Reviewer 6:
The reviewer stated that the researchers are on track and have accomplished a fair amount. The problem is complex and needs a wide range of scenarios to fully assess and overcome the barriers. Although the project is making progress, this reviewer commented that it will need to sustain the work, which is not an endorsement to continue the work after this funding expires. More emphasis on understanding what leads to the outcomes, as opposed to just showing the outputs, would be more helpful and improve usability of the output. The reviewer further commented that shortcomings in this area will make it hard to actualize or implement from theory to practice, and that the current output as presented does not translate well to real-world use. The reviewer indicated that the research team needs to be more grounded and clearer in what fundamental knowledge it will generate, versus showing results from a model.

Reviewer 7:
The reviewer stated that what was described in the presentation was not clear and concise, and that it was not clear how the development of a control strategy or model system for use in vehicles developed by this organization could be reduced to practice by vehicle companies.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer indicated that the research team appeared to have excellent collaborative efforts with other laboratories and outside organizations, including SMART Mobility Consortium members, Lawrence Livermore National Laboratory (LLNL) for aerodynamic drag three-dimensional modeling and wind tunnel data, LBNL for real-world truck platooning test data, and the National Renewable Energy Laboratory (NREL) for reports and insights on truck platooning testing. The reviewer added that the team is also working with Auburn University and the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC) for truck platooning data and RoadRunner model validation, and HERE for roadway data. During the questions and answers (Q&A) period of the presentation, the reviewer continued, the presenter also indicated that discussions had been held with an OEM to gain additional insights and understanding of vehicle control systems and how they can be integrated into RoadRunner.

Reviewer 2:
The reviewer observed good collaboration with outside groups. While it was not in the review material, the reviewer said it was good to hear that the team is working with OEMs to find useful partners for the work done so far.

Reviewer 3:
The reviewer indicated that, based on Slide 19, the team appears to be working with a good set of relevant partners. The reviewer thinks there is some room for improvement if an OEM could be engaged, and that there should be some attachment to researching any industry standards that are being framed that could affect the final results of the work.

Reviewer 4:
The reviewer noted that there seems to be coordination, and that collaboration, while not covered in detail, appeared sufficient. The reviewer commented that additional attention to this in the slide deck and presentation would have helped.

Reviewer 5:
The reviewer stated there was no evidence in the presentation regarding any well-established collaboration between the different organizations, and suggested the PIs explicitly state their roles and contributions across all tasks.

Reviewer 6:
The reviewer said increased collaboration with OEMs is needed to ensure optimal control assumptions are possible in a production setting, and to correlate results with currently developed CAV systems.

Reviewer 7:
The reviewer inquired as to how a control system can be developed without some collaborations with a vehicle company or a system supplier, and added that this is unthinkable. The reviewer suggested there be more sources of system requirements and data for the end product to be credible.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the next steps are appropriate, and the examination of uncertainty in the projected savings from Eco-Routing should be particularly useful.

Reviewer 2:
The reviewer stated that the topics for future research are appropriate, but it was not sufficiently clear how this work would be done (i.e., the approach).

Reviewer 3:
The reviewer thought the future work should be focused on getting this work out on the road. The reviewer commented that industry collaboration in this aspect would be key, yet it is missing. The reviewer concluded that there has been enough work done on the simulation level and it is time to move these technologies to the real word to evaluate the impact.

Reviewer 4:
The reviewer observed that planned future work builds off earlier efforts and results, and includes: the completion of eco-driving optimal control theory for multiple CAV scenarios and implementation of optimized predictive control for all variables; case study quantification of energy impact uncertainties and benefits for various powertrains; further development of RoadRunner, such as improving the human driver model and validation with real-word driving data; and development and validation of CAV scenario libraries. An FY 2019 objective of the research team is to release a version of RoadRunner to the public.

Reviewer 5:
The reviewer commented that the simulation environment and tools created will provide a foundation for not only ANL, but also across academia, government, and OEMs. The proposed case studies will provide valuable insight into common questions asked by those in the emerging CAV field.

Reviewer 6:
Acknowledging it is difficult to do in this research environment, the reviewer asked whether there is any method to estimate or balance against customer acceptability of any eco-driving theories. The reviewer also asked whether passengers will accept platooning scenarios where the follow distance is close or request to have more separation.

Reviewer 7:
The reviewer indicated that without collaboration for full system requirements, the future research can only be considered to be academic in nature rather than for development of a usable control system as is stated.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer affirmed the work is directly related to DOE's mission as it addresses questions related to energy implications of CAVs.

Reviewer 2:
The reviewer stated that the project supports DOE's SMART Mobility and EEMS program objectives in conducting early-stage research on energy impacts of CAVs and developing a CAV control simulation tool that can be used by researchers for assessing the impacts of CAV implementation.

Reviewer 3:
The reviewer said the simulation environment provides a cornerstone for many other DOE projects.

Reviewer 4:
The reviewer noted the project studied the potential vehicle energy consumption reduction via new and emerging technologies not previously widely available.

Reviewer 5:
The reviewer stated that, while the project is aligned with the objectives, there remains an appreciable gap between the model and informing practice and actual outcomes.

Reviewer 6:
The reviewer indicated that the concept of the project is relevant, but the way it is being developed it has limited chance for successful application.

Reviewer 7:
The reviewer observed that the research is trying to address the question of forecasting future fuel use (i.e., energy use) should connected vehicles become adopted.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed that collaboration resources are needed.

Reviewer 2:
The reviewer indicated that the research team did not mention any project activities deferred due to inadequate or unavailable resources, and therefore concluded the project needs were being met.

Reviewer 3:
The reviewer affirmed that the resources are sufficient, and that additional resources will not effectively or efficiently help overcome the gaps in the research.

Reviewer 4:
The reviewer noted that $1.5 million in funding should be enough to perform significant model development and data collection.

Reviewer 5:
It seemed to the reviewer that resources are more than what would be needed for the simulation work. The reviewer remarked that at this level of funding there should be also milestones for vehicle testing and validation.

Reviewer 6:
The reviewer stated that the research appears to have sufficient resources to complete the proposed activities.

Reviewer 7:
The reviewer indicated that resources appear sufficient to achieve milestones and objectives.

Presentation Number: eems017
Presentation Title: Impact of Connected and Automated Vehicle (CAV) Technologies on Travel Demand and Energy
Principal Investigator: Josh Auld (Argonne National Laboratory)

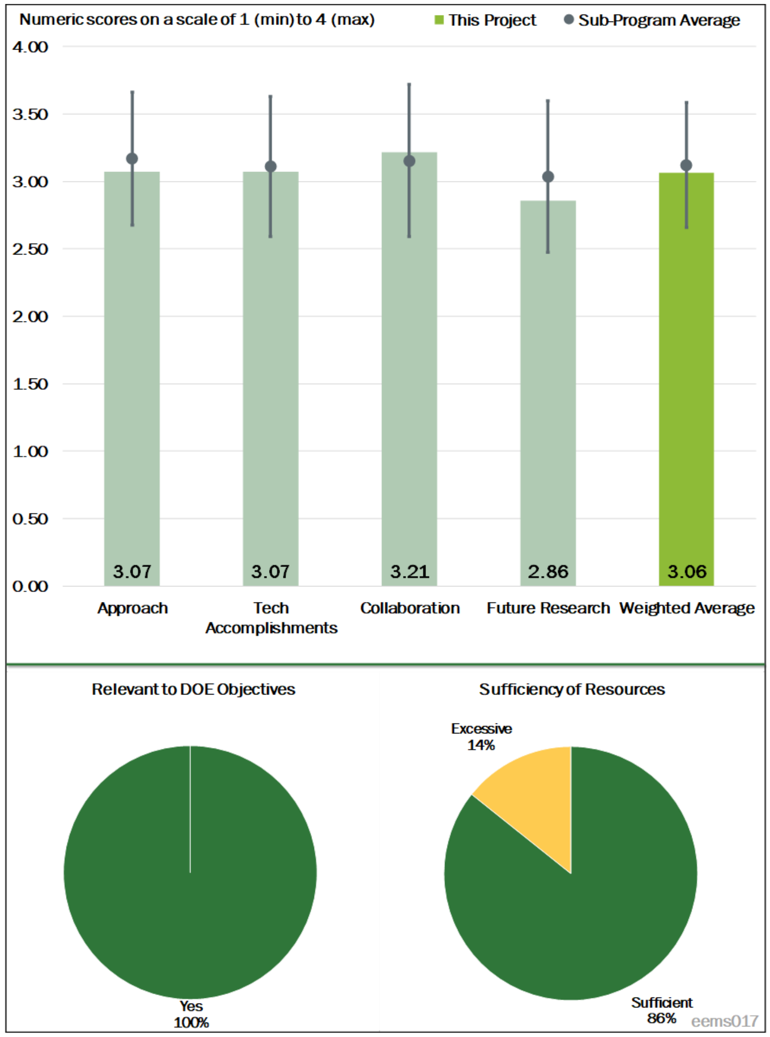

Figure 3-7 - Presentation Number: eems017 Presentation Title: Impact of Connected and Automated Vehicle (CAV) Technologies on Travel Demand and Energy Principal Investigator: Josh Auld (Argonne National Laboratory)

Presenter

Josh Auld, Argonne National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the project approach was very good.

Reviewer 2:

The reviewer noted that the project enables analysis of CAV impacts at the transportation system level. The approach is well-designed, with first studies being of privately-owned CAVs. The reviewer presumed a future task would also incorporate TNC CAVs.

Reviewer 3:

The reviewer stated that this was a well-laid out project.

Reviewer 4:

The reviewer appreciated the technical approach to the main question and commented that attacking this research as statistically as possible is good. The reviewer indicated that modeling customer choice, especially for future choices based in introduction of new choices, is not exact. The reviewer inquired as to how valuable the conclusions to planning for national energy use in 2040 are, as seen in the bandwidth of fuel and electrical energy use on Slide 19.

Reviewer 5:

The reviewer observed an overall strong approach to a novel problem, and noted that the use of activity-based modeling is appropriate. The reviewer had two suggestions for improving the approach if there are time and resources. The first is to consider adding a stochastic-based element to the analysis. Each variable could be given a range and then results would have error bars to demonstrate the sensitivity to inputs, none of which are certain. The second, and more important, is to give consideration for how this model of a limited geographic region might be scaled to address state- or national-level questions (e.g., data needs that would be required, or whether a more heuristic-based approach could be used). The reviewer said that, as is, this tool cannot address the question of national-level energy impacts and it is not clear if it could be expanded to do so.

Reviewer 6:

The reviewer noted that the approach starts out with a desire to develop a modeling tool that accommodates the mobility elements of the future, but that it surprisingly lacks any work to build the modeling tool to accurately perform on the mobility system of today before adding the new mobility elements. The reviewer stated that if this is being done it was certainly not reported, and without baseline validation of the new tool being employed, it is very concerning whether this tool will ever be accepted or useful by transportation system development agencies.

Reviewer 7:

The reviewer stated that the project fails to address the primary EEMS metric of Mobile Energy Productivity, and therefore the work has an improper focus. Producing measures of uncertainty are not useful unless they address the proper metrics. The reviewer also noted that EERE Leadership stated during the Q&A that this project should address the MEP metric during next year's work. The reviewer suggested that this project needs the participation of a couple of economists to inform the proper consideration of a utility model for evaluating the MEP metric.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that progress is excellent, and the main tasks for FY 2018 have been successfully completed.

Reviewer 2:

The reviewer noted that strong progress had been achieved and includes several important yet nuanced topics, such as estimates of energy impacts at lower levels of automation, effect on empty miles, and accessory load (which is an often-ignored parameter). The reviewer suggested that the project could be improved with some links to validation compared to experimental results, such as whether estimates of low-level impacts agree with experiments so far.

Reviewer 3:

The reviewer indicated that the project is only at the second quarter of FY 2018 per Slide 9, but that the regional impact analysis in the third quarter of FY 2018 would be quite interesting.

Reviewer 4:

The reviewer asserted that the approach of developing POLARIS appears to be very complete, and getting to the point of trusting the bandwidth data input and narrowing it to reach probability of energy use scenarios will be an interesting next step. The reviewer did not see the source of the 20% improvement in aerodynamics for platooning nor the source of the bandwidth of CAV accessory loading in the presentation.

Reviewer 5:

The reviewer expressed that the progress on creating a functional, integrated simulation framework for analysis of regional transportation characteristics is good, and it is likely that the framework can be adapted to producing useful results in the future. The reviewer said, however, that results to date indicate that the progress made misses the target objective of contributing to assessments of Mobility Energy Productivity.

Reviewer 6:

The reviewer remarked that, while accomplishments of the analyses were good, the project was very analytical and less oriented towards real-world application, similar to other reviewed projects.

Reviewer 7:

The reviewer commented that, based on the approach stated, the project team is making some but not great progress. The reviewer added that, because the approach is not considered great, technical accomplishment should have started with modeling the current system and validating it before embarking on modeling new elements.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The remarked excellent collaborative effort.

Reviewer 2:

The reviewer applauded the wide and impressive array of collaborators that were used to get the required data for implementing the study tasks.

Reviewer 3:

The reviewer commented that Slide 22 nicely laid out who was doing what. The reviewer would have loved to see the cost by partnership for this project.

Reviewer 4:

The reviewer observed that, based on Slide 22, the project team looks to be working with a good set of relevant partners. The reviewer thinks there is some room for improvement if an OEM could be engaged, and some attachment to researching any industry standards that are being framed that could affect the final results of the work.

Reviewer 5:

The reviewer affirmed that the project team has collaborated with other team members to produce this year's results.

Reviewer 6:

The reviewer noted that a list of collaborators was provided but without explanation.

Reviewer 7:

The reviewer observed that the project team is only collaborating with internal projects and with academic institutions, and that no transportation agencies or vehicle user groups. It was not clear to the reviewer where the appropriate number of use cases may come from to complete the modeling exercise, i.e., how many different ways would users plan to include a CAV in their household. One was shown but many other possible options need to be included. The reviewer said there is just not enough breadth of input parameters to assume this POLARIS product will be capable of the outcomes intended.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the next steps are appropriate and expand on the current work, and, per Q&A at project presentation, uncertainty analysis of the results will be tackled.

Reviewer 2:

The reviewer noted that everything the team suggested on Slide 24 appears to be improvements to the fidelity of the output.

Reviewer 3:

The reviewer expressed that future work is okay but may be incomplete to achieve the intended results. The reviewer said the end product of POLARIS from this project is not likely to be complete enough for general use for reasons previously stated.

Reviewer 4:

The reviewer observed a good proposed set of next steps that could be improved with incorporation of suggestions in both approach and progress sections.

Reviewer 5:

The reviewer stated that the project is absent of meaningful decision points where the work has sufficient forcing functions to change course based on feedback. The reviewer said the work plan indicated what is planned and has insufficient mechanisms for making significant course adjustments.

Reviewer 6:

The reviewer was puzzled by the comment that there are not enough data. The reviewer would have liked to see more simulations based on the team's assumptions on Slide 12. The reviewer asked why a value of time of $10/hour was used, where that came from, whether it is really $10, and whether it is a different number based on type of person, such as an executive who has limited free time. The reviewer found it interesting that the team utilized Bloomington, Indiana, but inquired about how many other cities are like Bloomington—perhaps this city is a good study point. The reviewer did not understand the family of graphs on Slide 21. Regarding Slide 20, the reviewer asked what the electrical load would look like for the city if Bloomington, Indiana was picked, and the reviewer suggested the team drill down there. The reviewer thought there is some more research that can be done just in this space, let alone moving into coordinated platooning.

Reviewer 7:

The reviewer noted that only a vague description of what is next was provided.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer highlighted that this is a great project, well laid out with assumptions, how to accomplish the questions posed, and then the results. The reviewer inquired whether there is a way to do better metrics across all of these projects such as the Red/Yellow/Green system used in the automotive world.

Reviewer 2:

The reviewer asserted the project is highly relevant to DOE EEMS objectives.

Reviewer 3:

The reviewer affirmed that determining the energy impact of CAVs is one of the key VTO objectives, and that the project is a big step forward in providing the required analytical tools.

Reviewer 4:

This reviewer is on the fence regarding the relevance of this project to support DOE objectives. The project appears to be consuming a significant amount of EEMS resources and should be producing meaningful results for the program. The reviewer commented that overall DOE objectives are to assess impacts of advanced mobility concepts in terms of Mobility Energy Productivity, and this project is missing the mark and will continue to miss the mark if it continues on its current trajectory.

Reviewer 5:

The reviewer said the project supports overall DOE objectives, but should be more practical real-world application as opposed to theoretical.

Reviewer 6:

The reviewer stated that the research is trying to address the question of forecasting future fuel use (i.e., energy use) should connected vehicles become adopted. The reviewer questioned how useful the results will be for this spending. If the bandwidth of expected energy use says that fuel use in 2040 will be anywhere between 0% and 80% reduced, and the use of electricity will be anywhere between 4000% and 11000% increased, the reviewer would question the usefulness of the results and the relevance of proceeding with the project.

Reviewer 7:

The reviewer stated that developing POLARIS is totally relevant, but getting it to a level where it can be very useful in this project is not clear.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer asserted that the project is on track with the given budget and resources.

Reviewer 2:

The reviewer indicated that materials did not appear to reference level of resources provided, but that progress seems in line with goals.

Reviewer 3:

The reviewer encouraged the project team to keep going and to figure out what has been learned so far and where to dive further with analysis, such as determining the number of cities in the United States that are like Bloomington, Indiana and diving down on the electrical grid side for the city. The reviewer further encouraged the team to keep going and stay organized like it already is.

Reviewer 4:

The reviewer could not really assess the resources well because the approach is not great. Within the current plan, the reviewer believed the current level of resources is sufficient.

Reviewer 5:

The reviewer commented that $1.9 million in funding should be enough to perform a significant model development and apply that model to create forecasts.

Reviewer 6:

The reviewer acknowledged that incorporating the results from other studies and expanding the phenomenology modeled required significant resources, and stated that the significant resources this project receives may need to be re-evaluated with respect to whether they can be used to more effectively address EEMS metrics.

Reviewer 7:

The reviewer assumed resources are sufficient, but was not clear on the remaining work and what resources are in place.

Presentation Number: eems019
Presentation Title: Smart Urban Signal Infrastructure and Control
Principal Investigator: H. M. Abdul Aziz (Oak Ridge National Laboratory)

Presenter

H. M. Abdul Aziz, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

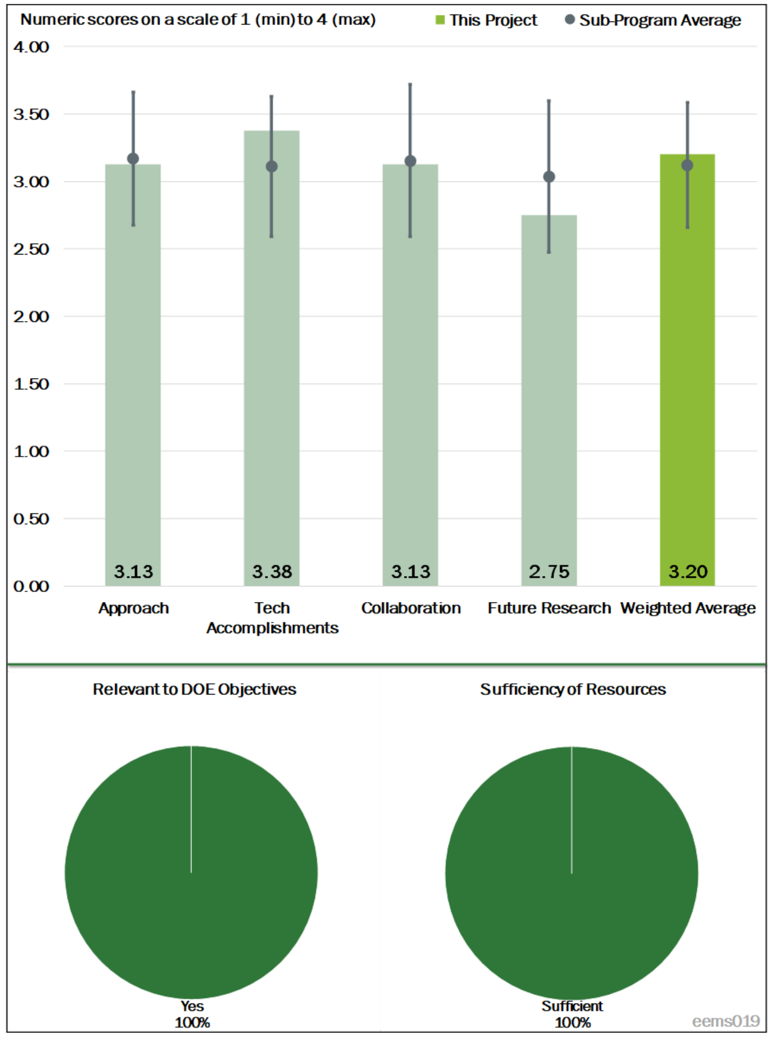

Figure 3-8 - Presentation Number: eems019 Presentation Title: Smart Urban Signal Infrastructure and Control Principal Investigator: H. M. Abdul Aziz (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer indicated that the research plan is reasonable for investigating the energy and mobility aspects of signal control schemes for a mixed CAV environment, with the final goal of developing a control system for control of a network of signalized intersections. The reviewer indicated that the primary objectives for FY 2018 were to develop signal control algorithms for energy reduction and assessing the impacts of CAV penetration levels on their performance, which seems in line with this progression.

Reviewer 2:

The reviewer stated that, overall, the control methodology and reinforcement learning (RL) techniques are sound and creating usable results. The reviewer added that, now that the heavy lifting is complete, the project would benefit from considering several real-world challenges, including the large delay in the control loop if communication is performed only using dedicated short-range communications (DSRC) vehicle-to-infrastructure (V2I), various levels of vehicle adoption of the vehicles communicating (i.e., when DSRC is less than 100% deployed), and the energy impacts for HEV, plug-in hybrid electric vehicles (PHEV), and battery electric vehicles (BEV).

Reviewer 3:

The reviewer indicated that the modeling approach has been successful in establishing the necessary parameters for the traffic signal control algorithms, and that the true test will come in the ability of first the modeling tools and then the algorithm applications to address the much higher complexity of a large-scale roadway grid with an integrated traffic signal system. The reviewer anticipates that this challenge can be met and the project is feasible. The reviewer suggested that the processing time of large networks using VisSim could create a production issue of case study work.

The reviewer noted that the prerogative of local traffic engineers in the responsible local government agencies will determine the operational priority of energy consumption, travel time and ultimately capacity of the roadway system. The reviewer recommended adding these types of operational management entities to the partners/collaborators in the final year of work to have meaningful input, which will help ensure that the signal control algorithms are suitably utilitarian.

Reviewer 4:

The reviewer commented that the project approach of using simulation to learn about traffic signal control algorithms that can implement energy minimization strategies is useful for adding to the EEMS knowledge base. The reviewer said that the bounding analysis that the team performed is a good first step. The reviewer would like to see a mapping of the entire scenario/experiment space. Without that mapping, this project comes off as a simulation tool building exercise.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said the project has produced some initial results that show that it is capable of producing relevant analysis results. The reviewer added that the tasks that the team is working on include a mix of practical technology features and fundamental controls analysis.

Reviewer 2:

The reviewer noted that the project has generated quite a few papers and provides a strong theoretical framework for intersection timing control for either energy-minimizing, time-minimizing, or some hybrid approaches. The reviewer added that this was one of the more math-heavy presentations among EEMS projects, and that the project members have demonstrated appreciated mastery of their RL tools.

Reviewer 3:

The researcher stated that project completion stands at 55% as of the AMR conference, which seems appropriate for a 3-year project starting in October 2016. In FY 2018, the research team completed a report on stochastic control algorithms and is on track to complete activities on stochastic control schema for corridor application and development of machine-learning control for energy and mobility goals. On the latter, the team has produced initial results and will be submitting a paper on results using the VisSim traffic simulator tool later in the year. The reviewer remarked that initial results were a little surprising from the standpoint of delay time associated with energy reduction achieved, but the team will be investigating ways to achieve energy/delay balance. The reviewer concluded that project output is reportedly strong, with five papers on research results submitted thus far.

Reviewer 4:

The reviewer expressed concern of the case study turn-around time to apply the reinforcement learning methodology, saying it will become much more difficult with the significantly more complicated large-scale traffic networks that are needed. The reviewer stated that this simple fact could jeopardize the schedule as the whole analytical process slows down, and strategies to address this issue would be important to address if the researchers agree this is a problem. The reviewer found the stochastic approach aspects confusing as it appeared this more conventional stochastic approach was a separate research project. However, the summary slide defined the FY 2018 approach to include both reinforcement learning and stochastic control theory work, so this understanding may be wrong, but this was not clear to the reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that, from this point forward, the addition of a few selected City Traffic Engineers to the collaboration process should be considered as the project phase moves into the application of the algorithms to traffic signal control. This practical insight would provide a better chance that the results of the study are used and applied in a manner that actually accomplished the purpose of energy efficiency, in light of the necessary tradeoffs between energy and delay time.

Reviewer 2:

The reviewer reported that, while the presenter stated work with Smart Mobility Consortium members, Pacific Northwest National Laboratory (PNNL), and NREL, no significant details were provided in terms of partner roles or the transfer of knowledge and benefits. PNNL is supporting the stochastic control work, while NREL is providing technical guidance. The reviewer indicated that the project is also getting assistance from Washington State University. The reviewer commented that last year the presenter discussed possible engagement with Smart City Challenge participants to develop relevant scenarios for smart signal systems and assess future control system needs for CAVs, but this did not look like it was accomplished to date.

Reviewer 3:

The reviewer commented that there is not much information relative to who is doing what on this project, and that it is difficult to accurately assess the collaboration and coordination attributes of this project.

Reviewer 4:

The reviewer stated that collaboration and coordination across the project team is hard to assess, as the balance between the two PIs and their institutions is not explicitly shown. The reviewer suggested that, although perhaps out of scope for this particular project, exploring real-world testing opportunities should be considered.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the diversity of the future work is good, and the project plans to explore the signal control algorithm’s features regarding scalability, fault tolerance, and advanced powertrain energy impacts.

Reviewer 2:

The reviewer commented that the future work planned for the project is appropriate concerning the original scope and approach, and involves additional sensitivity analysis of the energy/delay paradigm for the traffic control system, assessing the impact of advanced vehicle technologies such as start-stop within the context of the control system, and assessing the impacts of mixed traffic flows. For FY 2019, the team will be implementing the simulation platform for handling large-scale networks of signalized intersections and assessing the attributes for fault-tolerant signal control, and laying out sensor and data needs for real-world large-scale signal control systems. The reviewer reported that the research team will generate three paper deliverables in FY 2019 associated with these activities.

Reviewer 3:

It appeared to the reviewer that there needs to be a specific strategy for the machine learning application with the VisSim processing time for large-scale network models.

Reviewer 4:

The reviewer expressed that the overall feeling of the presentation is one of solid application of stochastic control and reinforcement learning to an overly simplified problem definition. The reviewer noted that planned ongoing (Slide 18) and future work (Slide 21) fails to consider more practical questions, such as performance under less-than complete vehicle penetration of DSRC and impacts of HEV/PEV powertrains, which differ significantly from internal combustion engine (ICE) cars in the stop-and-go environment under question. The reviewer said that no plans for a real-world—or even real-vehicle—testing are discussed.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer remarked that options for applying energy conservation to traffic signal control algorithms are in line with DOE objectives.

Reviewer 2:
The reviewer affirmed that the project supports DOE’s objectives by beginning to explore automated control strategies for traffic signals, and that the work is showing that it can provide incremental contributions to the EEMS knowledge base.

Reviewer 3:
The reviewer noted that the project supports overall DOE EEMS objectives in developing a large-scale signal control algorithm for CAV control.

Reviewer 4:
The reviewer commented that the work provides a good theoretical framework for stop-light control, and as such can evaluate various energy-minimizing or time-minimizing strategies. The reviewer observed that the focus appears to be on connected vehicles, despite all of the control taking place at the stop light instead of speed instructions directly to the vehicle. The reviewer affirmed this is certainly in scope for DOE and EEMS, but the project should consider other technologies such as automated driving and vehicle electrification.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that the project team is meeting its milestones using the budget provided.

Reviewer 2:
It appeared to the reviewer that the project is adequately funded for the activities presented.

Reviewer 3:
The reviewer stated that the budget seems reasonable for work focused on control theory and simulations. The reviewer suggested that a real-world testing proposal would naturally require more resources, but may be out of scope for the current project.

Reviewer 4:
The reviewer warned that the computational horsepower to perform iterative processing necessary for the machine-learning methodology may be a challenge for the research team. The reviewer suggested that DOE’s emphasis on HPC could be a means of addressing the problem.

Presentation Number: eems020
Presentation Title: Multi-Scenario Assessment of Optimization Opportunities due to Connectivity and Automation
Principal Investigator: Jackeline Rios-Torres (Oak Ridge National Laboratory)

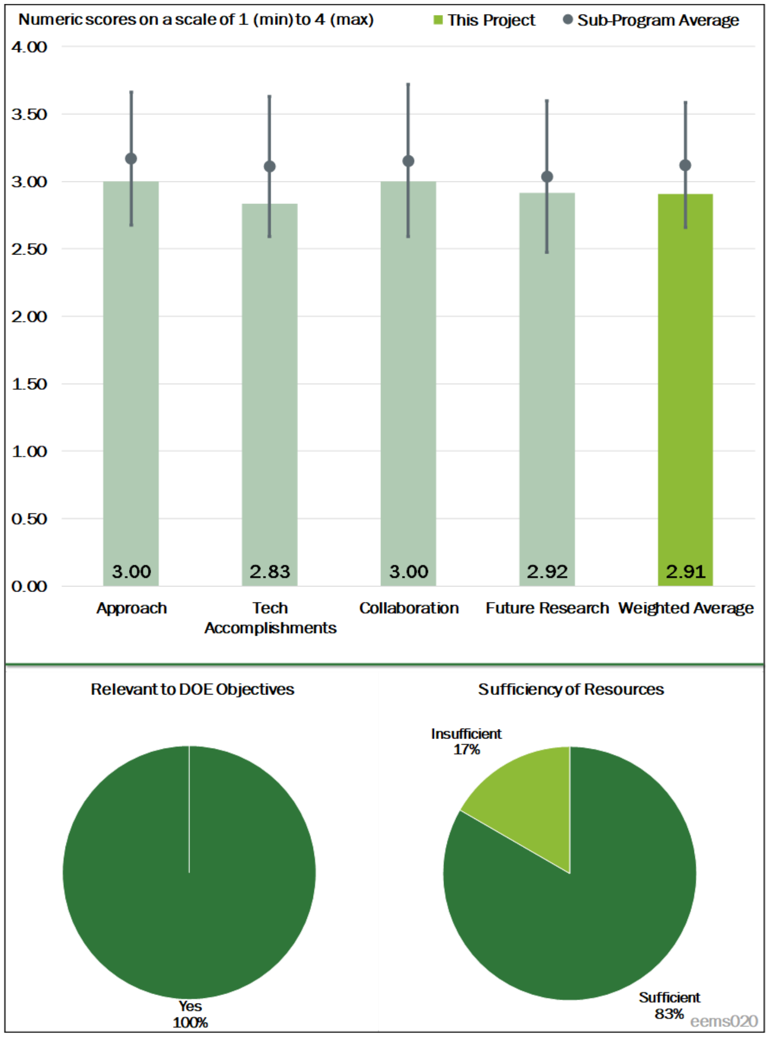

Figure 3-9 - Presentation Number: eems020 Presentation Title: Multi-Scenario Assessment of Optimization Opportunities due to Connectivity and Automation Principal Investigator: Jackeline Rios-Torres (Oak Ridge National Laboratory)

Presenter

Jackeline Rios-Torres, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that many of the questions or concerns held when previewing the slides were addressed in the presentation. Overall, the reviewer saw how this approach, particularly with how the project is trending (involving OEMs, bringing in safety metrics as an output rather than just as an input constraint, etc.), is robust overall.

Reviewer 2:

The reviewer stated that this project aims to develop optimal coordination strategies for CAVs to increase the mobility energy productivity. The reviewer commented that the existing six tasks and quarterly milestones are appropriate to achieve the project objectives.

Reviewer 3:

The reviewer noted that many elements of the work are good. The reviewer commented that, as shown on Slide 10, the simplification of fuel used to a surface should really help get to reasonable estimates much quicker than attaching an optimizer to Autonomie. Its drawback is that it is not able to get to the change in improvements due to various vehicle types and technologies. The reviewer remarked that as connected technologies are introduced, if they devalue the effectiveness of electrification, those technologies may get removed from the fleet for lack of cost benefit and the overall savings suggested from research projects like this one will not be realized.

Reviewer 4:

The reviewer noted that FY 2018 efforts have expanded to include additional highway scenarios beyond the initial highway merging scenario of last year. These additional scenarios will provide more insight on CAV energy impacts, especially in mixed traffic environments (less than 100% CAV penetration). The reviewer stated that the development of polynomial models that include additional powertrains for expressing system energy consumption should complement other work being done in the SMART Mobility space. The proposed investigation of vehicle communication instabilities on CAV control in mixed traffic environments for next year should be a key piece of work with possible synergies with other researcher's results in the area.

Reviewer 5:

The reviewer stated that the overall value and productivity derived from the connected driving is not clearly defined. The reviewer suggested that the magnitude of fuel and time savings for a given scenario needs to be described as part of bigger picture (i.e., answer the question of whether aggregate 40% fuel savings per event equals 0.5% or 5% of savings on an average total trip).

Reviewer 6:

The reviewer noted that this project seems to be using some useful tools and is exploring some relevant topics in sensible ways; however, the reviewer mentioned that the specific questions the work is trying to answer could be much more narrowly and clearly defined. A more thorough attempt to refine the questions and define the barriers would help the project team focus its efforts in a more meaningful way. The reviewer remarked that, for example, instead of saying the team is going to assess the implications of full or partial penetration of optimally connected CAVs in various traffic situations, take the definition of the goal to the next, deeper step by instead researching why full penetration of CAVs save energy and drive time in a heavy traffic scenario. The reviewer stated that researchers can then determine whether it is because the CAVs can follow closer, react more quickly, or accelerate more rapidly. From there the project team can vary those parameters to see their effect on CAV penetration in the overall vehicle population.

The reviewer noted that defining four or five main questions, in addition to sub or side questions, would add significantly more direction to this work and increase its impact. The reviewer stated that it currently seems like the project team is just running the models for some different traffic scenarios and waiting to see what pops out. The reviewer said that it would be better if the project team generated a list of questions they want to answer, collected data, and ran the models with the purpose of answering those questions.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked the team has developed a CAV optimal coordination algorithm that enables fuel consumption savings in diverse traffic conditions. Results for different scenarios show potential for up to 40% fuel consumption savings and up to 50% travel time reduction for full CAV penetration. The reviewer stated that low-traffic demand results in fuel savings, but medium- and high-traffic demand increases fuel.

Reviewer 2:

The reviewer stated that fuel comparison estimates need to include the added accessory loads for CAV. The reviewer noted that the lack of this is overstating the benefit. The reviewer expressed interest in seeing the stated improvements based on a more comprehensive driving pattern, and opined that, suggesting a 60% fuel saving for an on-ramp maneuver is overstating the true effectiveness of CAV technology.

Reviewer 3:

The reviewer estimated that this project to be about 40% complete as of the AMR conference. The reviewer observed that progress seems a little low given a project start date of October 2016. The reviewer pointed out that technical progress to date in FY 2018 included: introducing additional highway/traffic scenarios into the simulation model; assessing impacts of full CAV penetration for various optimally coordinated highway segments (merging roadway, intersection, roundabout, and speed reduction zones); developing insights on partial CAV penetrations of optimally coordinated segments; and developing various polynomial fuel consumption models based on Autonomie model data. Planned activities for the remainder of FY 2018 include a preliminary report on findings to date and initial work on assessing communication instabilities on CAV control.

Reviewer 4:

The reviewer remarked that mechanisms for fuel savings and time savings should be identified and quantified. Differences in fuel consumption meta-model for alternative powertrains should be highlighted, along with any work that attempts to quantify the benefit for electrified powertrains. The reviewer commented that the impact of communication instabilities should be comprehended in the overall noise factor assessment (weather, human driver behavior, etc.).

Reviewer 5:

The reviewer remarked that the results are very interesting so far, but not yet thorough, rigorous, or comprehensive in the reviewer's judgment. For example, the reviewer stated that there needs to be more outputs for safety (i.e., how is safety decreased, if at all, when fuel savings increases), as well as a number of human factors considerations (e.g., different types of drivers, how effectively CAVs can communicate with non-CAVs with respect to merging since so much of this is human to human today). Some of the apparent gains in fuel savings may be offset significantly by these considerations. Finally, the reviewer noted that controller/driver "effort" should be considered for the shrinking headways. In other words, if we assume the merge is safe for a moment even with smaller headways, there is still the possibility that to merge and maintain a particular headway, more vehicle jerking (as in the derivative of acceleration) may be required. The reviewer remarked that this jerking could become unacceptable to many passengers and drivers and therefore might need to be controlled in the analysis.

Reviewer 6:

The reviewer noted that the project has generated some insights about the impact of optimally coordinated CAVs on traffic flow, travel times, and energy use, but the presentation does not make clear exactly what the presentation meant by "optimally coordinated" or how deviations from the optimum would affect the results. The reviewer wondered how "optimal" is defined in this situation. The reviewer stated that the project also does not offer any evidence that the questions it is exploring are the right ones or even useful ones if answered correctly. The reviewer remarked that the progress is satisfactory given the fact that the overall purpose is not well defined, but if the purpose of the work were defined more narrowly then the reviewer thinks the accomplishments would seem much more impactful. For example, the reviewer suggested that the project team research what happens when a more realistic distribution of driver attributes is inserted into the model. The reviewer inquired as to whether the existing traffic flow would accommodate CAVs better or worse. The reviewer also suggested that the project team research if traffic flow would be improved or impeded if CAVs were programmed to keep a space between vehicles that is half what an average human driver would leave. The reviewer acknowledged that these may not be the right questions to identify, but the project team should be able to formulate better questions with the help of the U.S. Department of Energy (DOE) leaders. The reviewer commented that this would improve the technical accomplishments for the rest of the project from its current acceptable, but unimpressive, level.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that there seems to be strong collaboration among the overall project team. The reviewer's assessment increases from good to excellent based on the active pursuit of an OEM's involvement. The reviewer does, however, strongly think a tie to transportation and CAV safety expertise is very much needed for the ultimate results to be useful and relevant.

Reviewer 2:

The reviewer noted that this project is part of EEMS SMART Mobility Consortium and includes collaboration with NREL, Idaho National Laboratory (INL), LBNL, and Argonne National Laboratory (ANL). Other partners include the University of Delaware and the University of Tennessee. The reviewer noted that the project team is in active discussions with an OEM on potential collaboration for some validation work and discussion with Lyft for potential data sharing.

Reviewer 3:

The reviewer commented that the partnerships with government institutions in the SMART Consortium are good.

Reviewer 4:

The reviewer stated that per Slide 19, the project team looks to be working with a good set of relevant partners. The reviewer noted that there is some room for improvement if an OEM could be engaged, and some attachment to researching any industry standards that are being framed that could affect the final results of the work.

Reviewer 5:

Although working within the Smart Mobility Consortium was indicated by the researcher, this reviewer commented that specific collaboration with other laboratories within the Consortium was unclear. The reviewer stated that the project team is working with the University of Delaware on data from human in the loop testing for simulation validation, as well as the University of Tennessee regarding control communication-related issues. The project team did respond to a comment from last year’s AMR recommending OEM collaboration, reporting that active discussions have been held with an OEM regarding validation work as well with Lyft on data sharing.

Reviewer 6:

The reviewer commented that it is great that there are several different laboratories and universities involved, but that just as another reviewer from last year said, there appears to be little coordination between participants. The reviewer echoed last year’s comment, noting that it would be much better if the team would identify their roles and how they fit together. The project team should be able to say which laboratories are working on improving the fuel consumption algorithm, gathering data from industry and putting it in a usable format, and simplifying the code to make it run faster, etc. The reviewer noted that right now, there is no indication of who is doing what and why.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that appropriate future work is planned, including analyzing traffic flow/time/energy implications considering multiple lanes, heterogeneous traffic, interconnected scenarios and partial market penetrations. FY 2019 proposed activities include adding validation with human and hardware in the loop and strategies to improve efficiency under partial penetration and heavy traffic conditions.

Reviewer 2:

The reviewer pointed out that the proposed research shows a nice progression of work, expanding off previous results and focusing on new areas of interest. The research has progressively expanded highway/traffic modeling scenarios with the goal towards assessing integrated, regional highway systems. For FY 2019, the reviewer noted that the research will focus on CAV communication impacts on control and assessing optimal control framework for varying powertrains and CAV penetration levels in the context of additional highway/traffic scenarios. The project team also plans to validate the model with additional data obtained through outside collaborations. The reviewer stated that the project team should also look for additional collaborative opportunities with other laboratories with common work areas to leverage overall results and objectives.

Reviewer 3:
The reviewer referenced prior comments and remarked that the future work slide is largely on target, but could benefit from some of the previously mentioned enhancements. For example, while the project team acknowledged the need to incorporate more safety metrics in the analysis, including as an output to the various scenarios, the future work slide text did not mention this.

Reviewer 4:
The reviewer remarked that the suggested work in Slide 21 looks good provided that accessory loading is different for automated vehicles (AV) compared to non-AV vehicles, where for some scenarios the extra electrical load will outweigh the benefit for connected driving. The reviewer would like there to be clearer statements of the conclusions of the project team. There are many good graphs on CAV penetrations and traffic volumes, but no statements on critical mass of CAV or traffic volumes where effectiveness is rapidly increased or decreased.

Reviewer 5:
The reviewer noted that vehicle validation work is currently projected to be completed at the end of the project, which may be too late to integrate required learnings. Findings on actual energy and time savings as a result of vehicle response, propulsion system response, and behavioral constraints should be incorporated up-front in the analysis.

Reviewer 6:
The reviewer remarked that the project team has indicated how they want to expand the model by adding the capability of analyzing more complex traffic scenarios, such as multiple lanes, more heterogeneous traffic, and communication instabilities, to name just a few. The reviewer thinks these are fine, but it is impossible to know if these are the right enhancements of the model because the project team still does not know the specific questions they are trying to answer with the model. The reviewer stated that if that issue of better defining the technical barriers were addressed then the future research would align itself in a better way to address those barriers. The project team may be proposing the right future research, but there may be simpler efforts that would produce better insights.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted that this project is relevant to the overall DOE objectives of petroleum savings as it is exploring optimization scenarios for CAV integration that would result in energy efficiency improvements.

Reviewer 2:
The reviewer commented that the research is trying to address the question of forecasting future fuel use (energy use) should connected vehicles become adopted.

Reviewer 3:
The reviewer remarked that this research does support DOE EEMS and SMART Mobility objectives.

Reviewer 4:
The reviewer commented yes, the energy impact of CAV requires a coordinated effort from DOE and its partners.

Reviewer 5:
The reviewer stated that clearly this is relevant to both assess and potentially reduce fuel usage for future EEMS/CAV scenarios. The gap may be that there is not a very direct link to how these analyses will directly influence future policy and or assist technology developers in their work. The reviewer remarked that without strengthening this link, the relevance is more limited than it could be.

Reviewer 6:

The reviewer stated that if overall DOE objectives include understanding the impact of CAVs on general issues involving mobility, then the answer is yes. The reviewer said that the project team could do better and make the results much more relevant if they thought more about the questions/barriers up front, turned those into very detailed questions, and then collected the data and ran the models to answer those questions. The project team might fail to provide definitive answers, but the reviewer thinks the contribution to DOE's work on understanding the role of CAV's in future mobility would be greater.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that additional resources could lead to an improvement in scenarios analyzed and be used to engage outside partners (OEMS, national laboratories) for vehicle validation and data correlation.

Reviewer 2:

The reviewer said that it seemed as though the project team has been successful, and will likely remain successful in the future, based on the current funding level of approximately $340,000 per FY.

Reviewer 3:

The reviewer stated that this project has been funded around $350,000 per year for FY 2017 and FY 2018, which seems appropriate given its objectives and accomplishments.

Reviewer 4:

The reviewer remarked that the presentation did not list the 2019 forecasted budget. The reviewer noted that the $700,000 in funding for 2017 and 2018 total should be enough to perform a significant model development and analysis of this type. The funds appear to be in a good relative proportion to the more heavily funded, but also more complex projects, involving RoadRunner and Polaris.

Reviewer 5:

The reviewer stated that the FY 2018 funding level appears to be sufficient for the efforts prescribed.

Reviewer 6:

The reviewer remarked that the question of adequate resources is difficult to answer because it is not clear if one lab is using all of the approximate $330,000 per year, spread among several, or if there will be an increase in future funding. This level of funding should support a few people working part time on this project, which seems barely enough to support all the tasks if they include data collection, model development, and model utilization. Unfortunately, this reviewer cannot recommend providing more funding for this work until the goals and approach are more clearly defined. Only then can one assess whether the funding is adequate or not.

Presentation Number: eems023
Presentation Title: Whole Traveler Survey on Life Trajectories and Mobility Decisions
Principal Investigator: Anna Spurlock (Lawrence Berkeley National Laboratory)

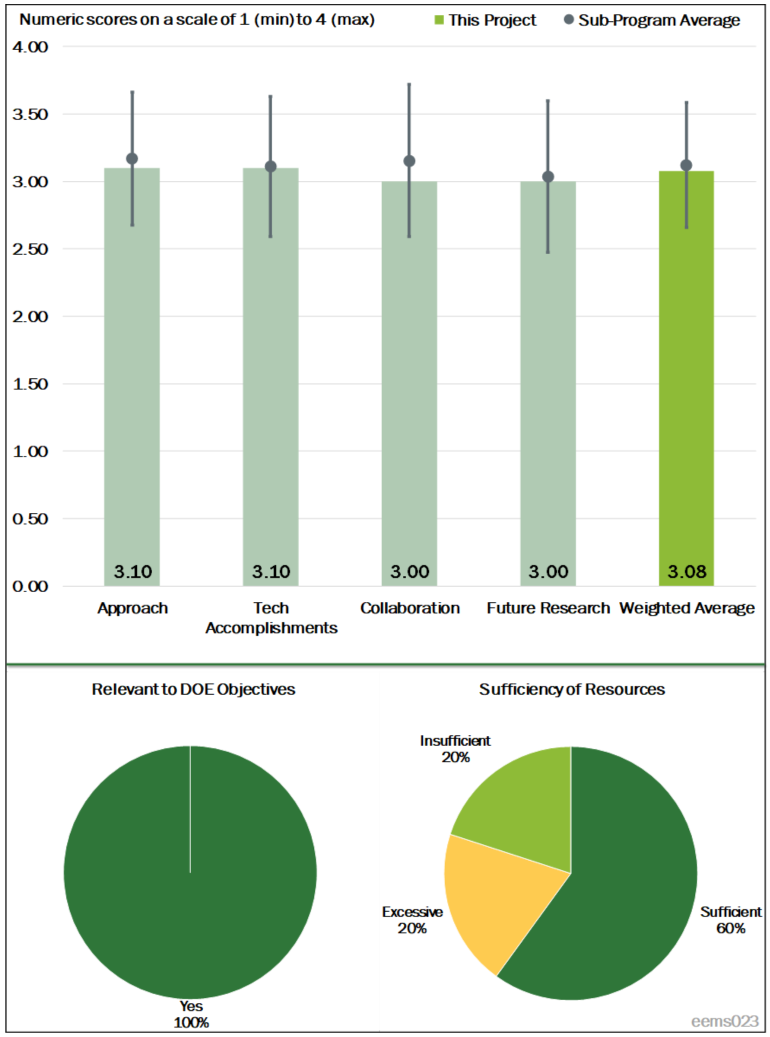

Figure 3-10 - Presentation Number: eems023 Presentation Title: Whole Traveler Survey on Life Trajectories and Mobility Decisions Principal Investigator: Anna Spurlock (Lawrence Berkeley National Laboratory)

Presenter

Anna Spurlock, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that this project had a good approach to personal dynamics related to transport.

Reviewer 2:

The reviewer stated that the phase one approach is to conduct a 20-minute consumer survey followed by phase two to collect global positioning system (GPS) based consumer travel data using Google location history for one week per person in the San Francisco area. This approach seems appropriate to the reviewer to obtain the desired 900 survey responses (3% anticipated response rate) and targeting 200 travel location participants. The reviewer commented that while this is good characterization of a specific urban area, it is not clear how transferable that data would be to other metropolitan regions. The project team should consider investigating how to apply the survey outcomes to other existing consumer datasets to extract EEMS-relevant information.

Reviewer 3:

The reviewer noted that the project team is looking at some important questions, such as how will future consumers make transportation mode choices, what types of personalities will adopt new technologies, and how will consumer choices about travel change over their lifetime. This focus on the people who are driving the demand for mobility is a somewhat new dimension for VTO research which has typically focused more on the vehicles and the technologies. The reviewer remarked that this project’s approach addresses behavioral questions much more directly than other VTO research. The interaction between mode choices, technologies, and traveler preferences is complex, and this work is likely to raise as many questions for future study as it answers. Although not discussed at the AMR, the role of e-commerce in future travel demand is important to study as it may (or may not) be a disruptor for transportation.

The reviewer stated that the approach of targeting the San Francisco Bay Area counties with surveys and data collections is reasonable given the other project considerations (alignment with existing models, variety of consumers that may represent future trends, and concentrated regional coverage). The PI demonstrated awareness of the limitations of the survey effort, both from a geographic standpoint and a survey response truthfulness standpoint, and indicated that conclusions drawn from the data would take this into account—which is important. The reviewer noted that the response rate expectations were reasonable for a random survey of this type. The reviewer said that the use of Google Locational History data collection efforts is a useful way of collecting GPS data without the need for additional hardware (assuming the survey respondent consistently carries the relevant Google-associated device). Depending on the accuracy needed, the reviewer commented that this could be used across other EEMS projects seeking to track the movements of a "mobility consumer" rather than tracking the movement of a vehicle.

Reviewer 4:

The reviewer stated that the process where survey and GPS data are "normalized" for use in other DOE research projects will be a challenge. Data collection and processing for other regions may be required to achieve full usefulness. The reviewer noted that the project is feasible for the development location of the San Francisco Bay Area.

Reviewer 5:

The reviewer commented that the primary objective of this project is to understand travel choice patterns, preferences, and decision-making processes with the advent of new mobility technologies across multiple time-scales. The project aims to understand how these patterns interrelate with multiple dimensions of heterogeneity across the population with regards to characteristics that do not change over time (e.g., personality characteristics) and change in predictable ways (e.g., lifecycle stage). Additionally, the reviewer noted that the project looks to provide insights and resources to improve the accuracy and flexibility of transportation system simulation models and reduce uncertainty associated with behavioral and human factors in transportation-as-a-system modeling and scenario analysis. The reviewer stated that the project presents two principal approaches, including survey-based data collection and cutting-edge analytics. The focus is on the impact of long-run lifecycle trajectory patterns, psychological and personality characteristics, and risk and time preferences. The reviewer remarked that it would have been beneficial if the team provided more detail upfront on the rationale for this approach as most of the discussion is very high level. There is additional information provided in the technical backup slides, especially on Slide 35 for "addressing gaps in current knowledge" and following slides on "life history calendar," "psychological/personality characteristics," and "time and risk preferences."

The reviewer stated that it would have been good for the project team to have explained this in more detail. Additionally, it may be good to include additional focus on economic factors as this is often the key determining factor. The reviewer noted that milestones for the project are provided but given the size and scope of the project, they are somewhat thin and lacking clear definition and high impact. It is not clear to the reviewer whether the project has established any go/no-go milestones, although Slide 31 mentioned a go/no-go milestone to be determined in Q3 FY 2018. The reviewer stated that overall, the project is reasonably well-designed and feasible.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that the project seems to be going well and is ahead of schedule.

Reviewer 2:

The reviewer reported that the survey has been launched after obtaining approvals, and noted higher completion rates for phase one and opt-in for phase two, as well as phase two completion.

Reviewer 3:

The reviewer stated that, in general, the accomplishments to date are appropriate given the scope of work and schedule. The project team has made good progress on completing the two phases of the project and has exceeded its targets for response rates, which is positive (particularly given the often-challenging nature of individual surveys). The sample size has grown to the point that the project team should be able to have enough data to discern the effects they are seeking. The reviewer noted that the project team's in-progress technical papers should be valuable for the broader research community and will be an important product of this work. The project team has worked to address some of the concerns expressed by reviewers in previous years, which should improve the overall quality of the research accomplishments.

Reviewer 4:

The reviewer stated that the progress appears to be ahead of schedule. The generation of papers documenting results and interpretations will be a key set of deliverables. The reviewer noted that the interpretation of data applicability outside of the San Francisco Bay Area—as much as the data allows—will be an important ingredient of project results.

Reviewer 5:

The reviewer said that the overall technical accomplishments and progress to date are satisfactory. Phase one survey activities are well on their way with the survey in the field with phase one completion and phase two opt-in rates higher than expected. The reviewer noted that the survey is on track for approximately 250 phase two submissions (which is greater than anticipated). The reviewer remarked that the team has identified three initial research activities including future-focused modal shift, characteristics of likely adopter, and long-term dynamic lifecycle stages. Research area one will focus on technological innovation as a driver of lower costs—behavioral shifts in choice—implications for the transportation system. Here, the goal is to estimate the effect of substantial decreases in the cost of ride-hailing on travelers' use of less energy-intensive modes or non-motorized modes. The reviewer noted that research area two assesses who is and will likely adopt these technologies and characterizing subpopulations across multiple dimensions of heterogeneity. Research area three focuses upon how barriers to technology adoption and mode choice may change as respondents pass through successive life stages. The reviewer concluded that research areas one and two have begun drafting of paper/analyses while research area three has finalized programming and piloting survey including a life history calendar with an innovated analytic approach for full lifecycle trajectory clustering.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that there is a large team at LBNL with one INL and two NREL contributors. The reviewer noted that the project is also using a subcontractor, Research Systems Group, for transportation survey design.

Reviewer 2:

The reviewer stated that the project team has secured participation from three DOE national laboratories and a research firm. The reviewer commented that the research/survey firm has experience with creating these types of surveys in the past and is an appropriate partner for this work to ensure the maximum amount of information is collected from survey respondents.

Reviewer 3:

The reviewer said that, at this point, overall collaboration and coordination are solid with three participating labs (LBNL, INL, and NREL) and Resource Systems Group, Inc. The reviewer suggested that it may have been beneficial to include an automotive OEM on the project as it is likely they would have excellent insights and marketing analysis into traveler characteristics that define consumer behavior with regards to transportation options. Automotive OEMs have been working in this space for a long time.

Reviewer 4:
The reviewer was not clear on the project’s collaboration efforts.

Reviewer 5:
The reviewer stated that the presentation reports that collaboration is challenging but underway.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the project team looks like they have a plan that will produce good data for next year.

Reviewer 2:
The reviewer noted that survey completion, data analysis and dissemination to appropriate EEMS research areas, and consideration of additional surveys or data analysis are very appropriate future steps.

Reviewer 3:
The reviewer stated that the future research plan is logical and reasonable given that the project is roughly two-thirds complete. The products of the research effort (insights in to other SMART Consortium tasks and public reporting) are appropriate for this type of work. The reviewer remarked that extending the data collection to another region would address one of the limitations of the work to date (single region of data collection) if time, approval processes, and budget allow.

Reviewer 4:
The reviewer noted that the stated objective of data collection in poor and underserved communities was offered in the presentation. The reviewer asked the project team to consider if the population characteristics of Oakland could be suitable for this and if a focused data collection could be possible in FY 2018 for this bus-population. The reviewer commented that this may need to be part of the determination for the go/no-go in FY 2019, but this would allow further analysis of this component of the population while staying within the original study area. Similarly, the reviewer stated that the suburban counties on the north side of the bay may also be a worthy target for additional surveys because these may represent a more common cross-section of the U.S. population.

Reviewer 5:
The reviewer remarked that the project’s proposed future research is satisfactory. Several high-level elements are presented including for FY 2018 completing data collection, delivering data to other SMART Consortium tasks, and generating an initial set of analyses and results for Whole Traveler Research activities. The reviewer noted that for FY 2019, the project is planning more extensive analysis and generation of results and insights. The reviewer stated that a more comprehensive listing and discussion of proposed future research would be beneficial, as would incorporation of additional hard decision points. This project is somewhat challenging as it can be difficult to determine what defines impactful progress.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
This reviewer said that this project is part of the SMART Mobility Lab Consortium and contributes to better understanding of pathways to an energy independent and efficient transportation system.

Reviewer 2:
The reviewer stated that this project is relevant to DOE VTO objectives as it is important to understand the characteristics of the ultimate customers of DOE-developed technologies. Understanding who is likely to adopt

these technologies and gaining insight as to why they would adopt them is critical in creating energy efficient vehicle technologies that will make inroads to the vehicle market.

Reviewer 3:

The reviewer stated that this project should support the nonphysical aspects of understanding transport decision making. This is an area the reviewer personally sees lacking. When this reviewer speaks with people in research areas, they seem not to be in touch with the realities of how people make decisions and what modes offset others and why.

Reviewer 4:

The reviewer noted that understanding of the "Life Trajectories" will be very important to apply in the numerous other research projects needing these data for travel and trip inputs to operational studies of future years, and the associated energy implications.

Reviewer 5:

The reviewer commented that this project is relevant to DOE's overall objectives to reduce energy use and improve mobility energy productivity. The reviewer noted that is important to understand (and ultimately respond to) individual traveler behavior and economic drivers to successfully influence future consumer receptiveness to and adoption of emerging and transformative transportation technologies and services.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that when the applicability of the methodology to data collection in other regions and part of the U.S. are considered, the additional funding to use the survey tools and analysis methods in a better cross-section of the American population is an important step. The reviewer recommended additional funding.

Reviewer 2:

The reviewer stated that the $3.35 million in funding for the three national laboratories participating in this project over 3 years seems appropriate given the large scope of the survey and the planned data analysis.

Reviewer 3:

The reviewer said that the funding resources should be sufficient to complete the project scope as described in the presentation. The data collection/survey geographic scope is sufficiently narrow for ensuring the project can collect data within its funding limitations.

Reviewer 4:

The reviewer assumed resources are sufficient for the project to achieve the stated milestones in a timely fashion, but resources are unclear.

Reviewer 5:

The reviewer commented that this is a significant project spanning 3 years with a budget of $3.35 million. Given the project's size, scope, objectives, and milestones as defined, the budget seems somewhat excessive. The reviewer noted that the project may benefit from identification of much sharper and definitive milestones and deliverables, especially with regards to supporting other SMART Mobility project tasks.

Presentation Number: eems024
Presentation Title: Market Acceptance of Advanced Automotive Technologies (MA3T)—Mobility Choice: Analyzing the Competition, Synergy, and Adoption of Fuel and Mobility Technologies
Principal Investigator: Zhenhong Lin (Oak Ridge National Laboratory)

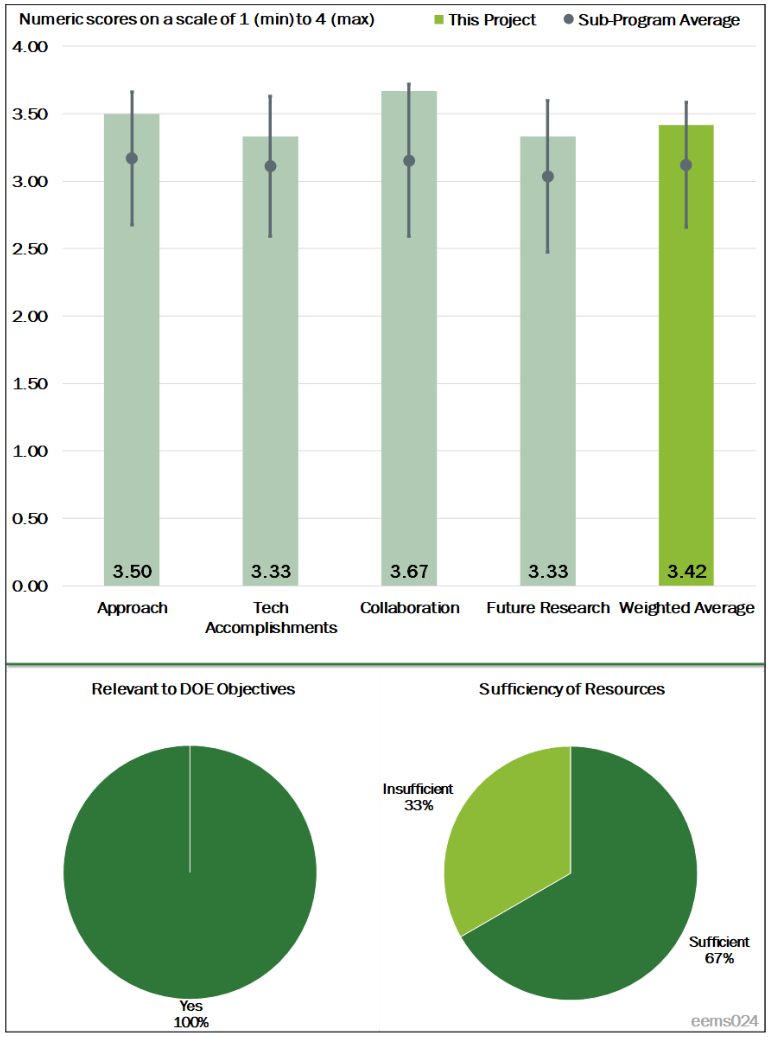

Figure 3-11 - Presentation Number: eems024 Presentation Title: Market Acceptance of Advanced Automotive Technologies (MA3T)—Mobility Choice: Analyzing the Competition, Synergy, and Adoption of Fuel and Mobility Technologies Principal Investigator: Zhenhong Lin (Oak Ridge National Laboratory)

Presenter

Zhenhong Lin, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the approach outlined is appropriate for achieving the work scope. The new choice modeling approach builds on Oak Ridge National Laboratory's (ORNL) well-established market acceptance of advanced automotive technologies (MA3T) model framework, which is likely more cost-effective than creating an entirely new model. The reviewer stated that for the long-term choices, including the "not buy" option is very important particularly in light of some concerns that future vehicle technologies will be too costly for many vehicle buyers to adopt. The project team has included a useful coordination/calibration aspect to its approach to take advantage of other EEMS research results.

Reviewer 2:

This reviewer stated that the project has an excellent approach for accelerating the acceptance transition to new mobility technologies. The project is modeling business cases associated with various levels of penetration of EVs and AVs. The reviewer noted that the project leverages several years of previous development of the MA3T model and uses cost data from ANL.

Reviewer 3:

The reviewer noted that the project team is using an analytical approach to understand future penetration and acceptance of electrification, shared, and autonomous transportation using various consumer choice models, etc. The reviewer said that this rational approach is likely to provide a good forecast of future scenarios and their relative probabilities.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the accomplishments to date are good given that the project is less than a year old. The project team has already made initial model runs to explore market uptake of automated vehicles by fuel type, including the number of plug-in electric vehicle (PEV) and HEV systems being adopted in the automated vehicle market (of interest because of the general belief that electrification and automation have opportunities for synergies in a number of areas). The reviewer noted that the project team is using the models to explore interesting effects such as the benefits to human drivers of reduced congestion through automation (and the implications for further automated vehicle uptake), which should add to the discussions and understanding around automated vehicle effects.

Reviewer 2:

The reviewer stated that the project analysis results present a clear story regarding what the team has estimated and the significance of each of the results.

Reviewer 3:

The reviewer said that the project team has presented several interesting plots of future fuel types, future market shares of various technologies, etc. The reviewer stated that these interesting results offer a nice preview of how transportation preferences may evolve in the future.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the project team is taking good advantage of the full suite of SMART Mobility project results as inputs and the national laboratories/universities associated with those activities. No other collaborations are explicitly listed (all the work is done at ORNL).

Reviewer 2:

The reviewer remarked that the project presentation showed that all the partners are contributing significantly to the work products.

Reviewer 3:

The reviewer stated that several of the results and accomplishments are joint with other national laboratory teams as well as university partners. The reviewer remarked that this shows good coordination and collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the future work to complete the development of the model and its planned functionality and refine the model as needed is logical. The reviewer remarked that the project team should have the necessary expertise and resources to complete this work.

Reviewer 2:

The reviewer noted that the project's future work plans are primarily to refine its assumptions and representations. The project team will likely continue to improve the value of their quality work products.

Reviewer 3:

The reviewer stated that the project team has proposed interesting future work on the value of commute time and the supply of shared mobility.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer stated that understanding how consumers make choices about vehicle technologies is very relevant to DOE VTO goals as these technologies do not improve energy efficiency if consumers do not ultimately adopt them. The reviewer said that exploring multiple scenarios and identifying the range of results is very important to bracket the problem.

Reviewer 2:

The reviewer commented that building models of autonomous vehicle business cases and penetration scenarios is directly relevant to achieving the EEMS program objectives.

Reviewer 3:

The reviewer stated that EEMS aims to study ways to reduce future transportation energy use by all means possible (shared, AV, electrification, multi-mode, etc.) This project supports this objective by studying market acceptance and adoption of these innovations.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked that this project may be deserving of more resources. The project team has produced strong results with the limited resources given.

Reviewer 2:

The reviewer stated that the resources listed do appear to be sufficient to complete the work described.

Reviewer 3:

The reviewer commented that the project team has made good progress with the allotted resources and they expect the team will handle the future work adequately.

Presentation Number: eems026
Presentation Title: Expanding Regional Simulations of Connected and Automated Vehicles (CAVs) to the National Level and Assessing Uncertainties
Principal Investigator: Tom Stephens (Argonne National Laboratory)

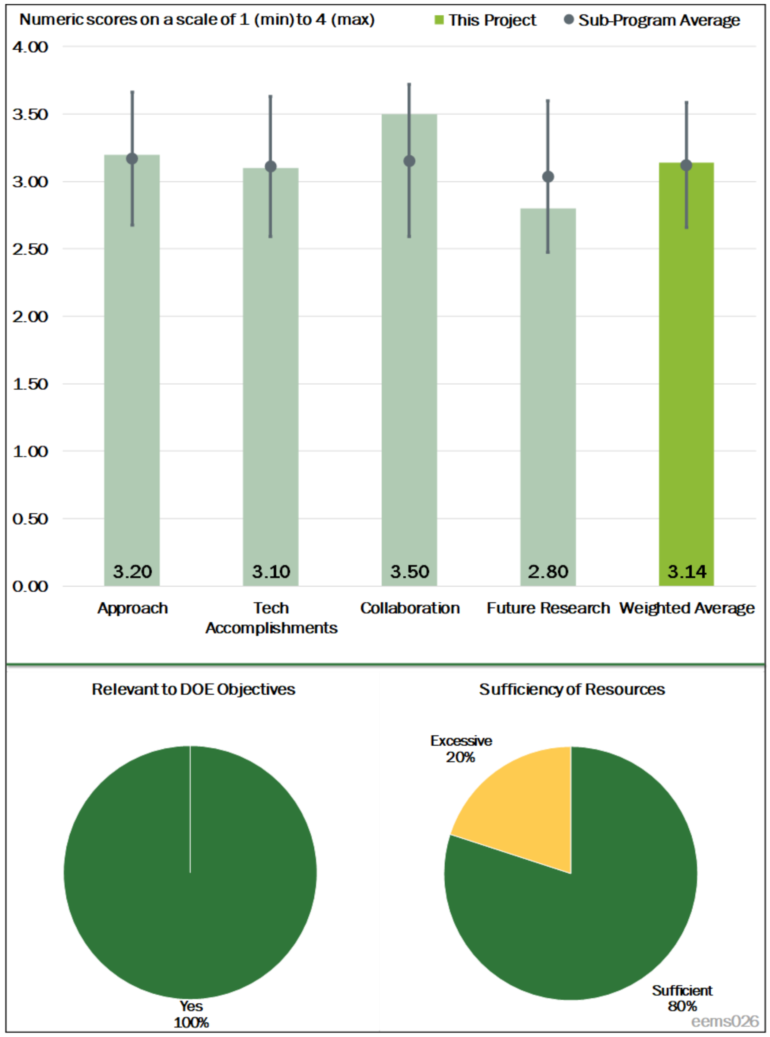

Figure 3-12 - Presentation Number: eems026 Presentation Title: Expanding Regional Simulations of Connected and Automated Vehicles (CAVs) to the National Level and Assessing Uncertainties Principal Investigator: Tom Stephens (Argonne National Laboratory)

Presenter
Tom Stephens, Argonne National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer commented that the approach is logical and will provide the desired improved understanding of CAV energy impacts. The combination of bottom-up and top-down analysis efforts makes the overall results more defensible as the team can show multiple approaches to identifying the high-level CAV impact and explore more scenarios to define the space better. The reviewer stated that the team is making good progress in integrating these formerly-separate projects together. The step to review the existing literature is very important to ensuring that the research is focused on filling the most critical knowledge gaps. The reviewer said that given the pace of technology development and the likelihood of CAV technology uptake in commercial medium-duty (MD)/heavy-duty (HD) trucks, including HD vehicles as part of the analysis for this task is welcomed.

The project team appears to be working well to incorporate the results of other EEMS research and taking advantage of this body of work (making efficient use of overall VTO funding). The reviewer remarked that the project team is looking at both vehicle miles traveled (VMT) (energy impact) and passenger miles traveled (mobility service demanded) and both are important to understanding the impacts of CAVs.

Reviewer 2:
The reviewer noted that the project team has chosen a bottom-up and top-down approach.

Reviewer 3:

The reviewer remarked that the project aims to address gaps in understanding and estimating potential energy and mobility impacts of CAVs at the national level. Specifically, the reviewer pointed out that the task aims to develop methods to estimate potential CAVs technology adoption rates, develop methods to aggregate detailed results of case studies to the national level, develop response-surface/reduced form methods to give technical/behavioral outcomes at the regional/national level, and apply methods and deliver estimates of national level energy and mobility impacts of CAVs. The reviewer stated that project approach encompasses a literature review and conducting two approaches to national-level analysis including bottom-up (including estimates of CAV adoption and traveler and vehicle simulations) and top-down (economic modelling and energy/travel effects from results and response functions from larger, disaggregated spatial models). Use cases include cooperative adaptive cruise control (CACC), highly automated passenger vehicles (private/shared), and HD vehicles.

The reviewer noted that given the inherent uncertainties of predicting future scenarios and the degree and impacts of CAV adoption, it is good to assess from several directions including bottom-up and top-down. However, the reviewer would have benefited from a more thorough explanation of how the two approaches are best merged together and assimilated to provide more robust and defensible assessments and predictions. Later in the presentation (Slide 17), the presentation mentioned that CACC penetration levels in a fleet are compared with that predicted by the 2017 Annual Energy Outlook (with different methodology and some assumption differences). The reviewer remarked that it may be beneficial to do more of these "sanity checks" in a number of areas with other sources to refine and validate the approaches being used in this project.

Reviewer 4:

The reviewer remarked that this is an ambitious project. The approach to addressing computational complexity is plausible, but the adequacy of the bottoms up methodology to reproduce national-level activity is not entirely clear. The reviewer noted that it is important to clarify whether the goal of this project is to generate sound results (less likely) or useful analytical approaches that could be further developed (more likely). The large AV advantage due to range extension (Slide 11) appears to assume battery costs that are very high in 2050.

Reviewer 5:

The reviewer liked this project's approach of using both a bottom-up and top-down process to calculate estimates for some key parameters, such as fuel use and VMT. These different approaches can then be compared and evaluated for whether they are producing results that make sense. The reviewer noted that could be done by comparing the predictions for nationwide fuel use in transportation with actual data regarding the amount of fuel sold by fueling stations or provided by the oil companies, which should be available. However, the reviewer did not feel that at least two of the barriers identified in the presentation are either real barriers or are well-posed. Neither the "computational difficulty of accurately modeling large-scale transportation systems" nor the "complex role of human decision-making processes" is really a barrier. The reviewer noted that the first is the reason we need models and the second is one of the things we need to model.

The reviewer said this project would be improved if the research team would better define exactly what it is they want to model, what it is they want to learn from the model, and what barriers need to be overcome that are making this difficult. The reviewer stated that saying that something is "complex" is not sufficiently specific. The reviewer suggested that a better set of goals and barriers could be modeling energy use by CAVs (and conventional vehicles) in several canonical driving scenarios (urban, rural, etc.) and applying these at a national scale so that the project team can learn whether CAVs will increase or decrease energy use and how that relationship between adoption level and energy use changes with level of CAV adoption. However, the reviewer noted that there are no accurate data yet on how CAVs interact with conventional vehicles (or vice versa) so the project team may need to make assumptions or estimates about this interaction and then test these assumptions on small sets of vehicles. The reviewer remarked that this same line of thinking could be applied to predicting travel times or traffic flow or other parameters of potential interest. While the current approach has some merit, it could be made much better if the goals and barriers were expressed better using more specific language. Without that, the reviewer stated that it hard, if not impossible, to comment on feasibility.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the project has demonstrated a number of accomplishments, including development of initial national-level impacts from top-down analyses; using the MA3T-Mobility Choice model to identify and establish critical insights on the market dynamics of vehicle electrification, automation, and sharing; establishing that travel patterns (travel demand and VMT) can be transferred to similar households; using VMT transferability modeling to expand detailed travel simulation results to the national level; establishment and initial testing of a national-level aggregation framework; and exercising the framework through hypothetical examples. The reviewer concluded that the project appears to be roughly on schedule.

Reviewer 2:

The reviewer commented that the project team has made solid progress on evaluating the national level impacts (top-down)—fuel use versus fuel incremental cost; VMT versus VMT incremental cost; market dynamics of vehicle electrification, automation, and sharing; and transferability of travel patterns to households with similar characteristics.

Reviewer 3:

The reviewer noted that the project seems to be on schedule, although the presentation makes reference to awaiting results from other SMART Mobility tasks.

Reviewer 4:

The reviewer commented that, in general, the accomplishments seem to be reasonable given that the team is around 60% complete on a schedule basis. The consideration of purchasing decisions is an important aspect of CAV technology that will drive the uptake and resulting energy use. Both technology choice and decisions about buying or not buying a vehicle are essential options to examine to understand CAV markets. The reviewer noted that any effort by the team (or EEMS in general) to expand the choice models to MD/HD vehicles would be useful as purchase decision processes for MD/HD are different from light-duty (LD) and must be understood. The examination of VMT-based pricing is particularly interesting and shows some intriguing but probably expected trends (consumers will request more VMT if it is less expensive per mile).

The reviewer remarked that including insurance cost is valuable as this is relatively unexplored in CAV technology. This reviewer hoped the team can review results with an insurance company as a reality check if they have not done so already. The transferability analysis seems reasonable but is easy to dispute. The project team should be able to demonstrate how this process provides reasonably accurate answers (and it appears the team has done this work although there is limited time in these presentations to provide such details). The project team has made good attempts at responding to reviewer comments with thoughtful answers and adjustments to work where necessary.

Reviewer 5:

The reviewer commented that it is difficult to tell from this presentation precisely which accomplishments this work produced and which ones were produced by other, related projects. For example, regarding the graphs shown on Slide 10, the reviewer asked if they were from this work or some other project. The information on most of the slides labeled as containing accomplishments is not phrased in a manner that suggests they are really accomplishments. Phrases such as “quantify utility to consumers” and “transfer results from” seem to indicate what the project team is currently doing, not what they have completed or accomplished. The reviewer remarked that if the work is trying to predict when consumers will choose a CAV or what their adoption rate will be, then there needs to be some model or criteria for consumer decision-making. The reviewer noted that this is never defined. The reviewer asked if it is based purely on an economic calculation; if there is a benefit-cost ratio where the decision turns in favor of the CAV; if there is a societal benefits part of this calculation or just personal benefits; if these different benefits are weighted the same; if there are historical precedents for such decisions; and if government regulation requiring CAV adoption would produce more societal benefits more quickly. The answers to these questions could signify technical accomplishments. The reviewer stated that the project seems to be producing some information through the modeling, but because it does not seem to be aimed at specific goals or questions, it is hard to call these accomplishments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the project integrates work across team members through the top-down and bottom-up approaches. It also makes use of and feeds into other EEMS/SMART tasks, as well as informal collaboration with other institutions.

Reviewer 2:

The reviewer noted that the project team has been making good progress in integrating this work with activities at other EEMS-related national laboratories (ORNL, NREL) and universities (University of Illinois at Chicago). The team is drawing on work from others rather than recreating it wherever appropriate (a good use of resources) and sharing results back with other national laboratories doing work in this area.

Reviewer 3:

The reviewer stated that the project team has shown good coordination between ORNL, NREL, ANL and University of Illinois at Chicago (UIC).

Reviewer 4:

The reviewer remarked that overall, the collaboration and coordination are excellent for the project. The project has three primary national laboratory participants (ANL, NREL, and ORNL), the UIC, and the University of Maine. The reviewer noted that the project is also working to incorporate outputs from additional SMART Mobility performers (LBNL and INL), as well as informal collaborations with University of Michigan, Vanderbilt, and the U.S. Environmental Protection Agency (EPA) Office of Transportation Air Quality. The reviewer concluded that the project could possibly benefit from a private sector participant to provide a commercial perspective and sanity check.

Reviewer 5:

The reviewer stated that the project seems to be receiving results or predictions from other projects or collaborators so the reviewer is giving it the benefit of the doubt that the coordination is good. However, it would be much better if the presentation identified exactly which collaborator (or team member) is doing what and exactly what information each member produces and who is transferring what to whom. Slide 8 hints at this but it is never clarified on the other slides and slides like Slide 16 leave the reviewer wondering where that information was generated. The reviewer noted that this project needs regional-level information from other projects, which the reviewer has to assume it is getting or there would be very little to present, but it would be much better if the project team members could or would be clearer about exactly what they are producing and transferring to each other and why.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the proposed work includes incorporating behavioral research results, which will be important to ensuring value of this work. The reviewer pointed out that it was not specified how those results will be incorporated.

Reviewer 2:

The reviewer commented that the future work proposed by the project team seems to be reasonable and will round out the accomplishments to date. As noted elsewhere, including MD/HD trucks is very important in understanding the overall energy impact of CAVs. The reviewer stated that the sensitivity analysis to explore the analysis' response to assumptions is also important in increasing confidence in the overall results.

Reviewer 3:

The reviewer stated that future plans include applying aggregation methods to CACC scenarios, estimating the potential for CAVs by market segment, etc. The reviewer said that these are all good objectives.

Reviewer 4:

The reviewer noted that the project defines a somewhat broad scope of proposed future work for FY 2018 and FY 2019, ostensibly addressing many of the remaining challenges and barriers as identified on Slide 20. However, the reviewer said that the scope may be too expansive and it may be beneficial to narrow it somewhat. Focusing more heavily upon further testing and validation of the approach may help build confidence in its validity and applicability. The reviewer pointed out that there is little discussion of appropriate decision points nor methods to reduce risk by providing alternate development pathways for future work.

Reviewer 5:

The reviewer noted that many slides are poorly prepared. The reviewer commented that, for example, every bullet point should use the same verb tense in Slides 20 and 21, instead of using words like "validating" or "extending" in some places and "expand" or "analyze" in others. The reviewer stated that the simple tense (will validate) is preferable to the progressive tense (will be validating).

Secondly, the reviewer stated the project team should use complete sentences and complete thoughts. The reader/reviewer wants to know what the researcher is going to do, so the reviewer suggested saying something like "in the next year we will…," not "validating transferability of VMT." And in formulating those complete thoughts, the reviewer advised that the project team avoid using undefined words and phrases. Phrases like "expansion aggregation methods" and "simulation results for CACC scenario" need to be clearly defined. The reviewer remarked that the project team put a lot of bullet points on Slides 20 and 21 so it seems that considerable thought had been given to what the project team wants to do next. Unfortunately, the slides do not clearly communicate what that is or how it relates to the goals or why those funding the research should care about it.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer stated that this project supports DOE objective of reducing petroleum consumption and the EEMS objective of decoupling mobility from energy use.

Reviewer 2:

The reviewer remarked that understanding the impacts of CAV technology at a broad system level is very relevant to DOE objectives, especially because the initial estimates of impact are quite uncertain. It will be very important to scale-up detailed case studies and simulations to assess national-level impacts to help inform DOE research. The reviewer commented that it is critical for VTO to understand CAV technology impact in light of its mission of national energy security.

Reviewer 3:

The reviewer stated that aggregating local effects to national totals in the area of adoption of electrification, sharing, and autonomous technologies supports the EEMS objective of reducing energy consumption via a full system approach.

Reviewer 4:

The reviewer commented that yes, the project is relevant to overall DOE objectives in that it aims to estimate the potential energy and mobility impacts of CAVs at the national level. This information is needed to help provide knowledge and insights as to which CAV technologies within specific applications offer the greatest potential to help address the nation’s transportation energy and mobility challenges.

Reviewer 5:

The reviewer remarked that DOE clearly wants a better understanding of the future impact of CAVs on the transportation and energy systems. This project is trying to create some models at the national level that address that. However, the reviewer stated that the goals of this project need to be much more specific and the research questions need to be much clearer before one can say whether this project is providing DOE with valuable insights on the impact of CAVs. It is not exactly clear whether the project is trying to model consumer purchase decision making with respect to CAV’s and then use this to predict their adoption rate or if it is simply assuming adoption rates and trying to predict their impact on energy use and mobility. The reviewer stated that either approach might have some value, but the project is not clearly addressing one or the other objective or both or something else. The language describing the work is too vague.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked that this is an ambitious project, but the project team plans to take advantage of results from other projects, so resources may be sufficient.

Reviewer 2:

The reviewer commented that the resource level appears sufficient to achieve the goals of the project.

Reviewer 3:

The reviewer remarked that the resources are adequate for the stated objectives.

Reviewer 4:

The reviewer commented that from the presentation, it appears that DOE has provided a total in FY 2017 and FY 2018 of approximately $1.2 million for the project. The project is scheduled to conclude in September 2019. The reviewer said that not knowing what FY 2019 allocations are likely to be, it is somewhat difficult to assess if the resources are sufficient. However, assuming that FY 2019 funding will be in the neighborhood of $500,000, it would appear that funding resources are sufficient for the identified project scope.

Reviewer 5:

The reviewer commented that these questions about resources on the EEMS projects are almost impossible to answer based on the information that is provided in most of the presentations. The budget for this work seems to be rising from about $400,000 in 2017 to $760,000 in 2018. But it is not clear how these funds are divided between researchers and institutions or if there are additional funds beyond these that the other team members are receiving. In either case, the reviewer concluded that this is significant funding for a project that is not generating its own data but is receiving inputs from other programs and simply finding ways to scale these to a national level through modeling. The reviewer does not think the resources are wildly excessive, but they seem a little high for such an effort. The reviewer stated that a clearer picture of the precise research goals, the roles of the other team members, and the budget allocation for each team member would be needed before providing a better answer to this question.

Presentation Number: eems027
Presentation Title: National Scale Multi-Modal Energy Analysis for Freight
Principal Investigator: Kevin Walkowicz (National Renewable Energy Laboratory)

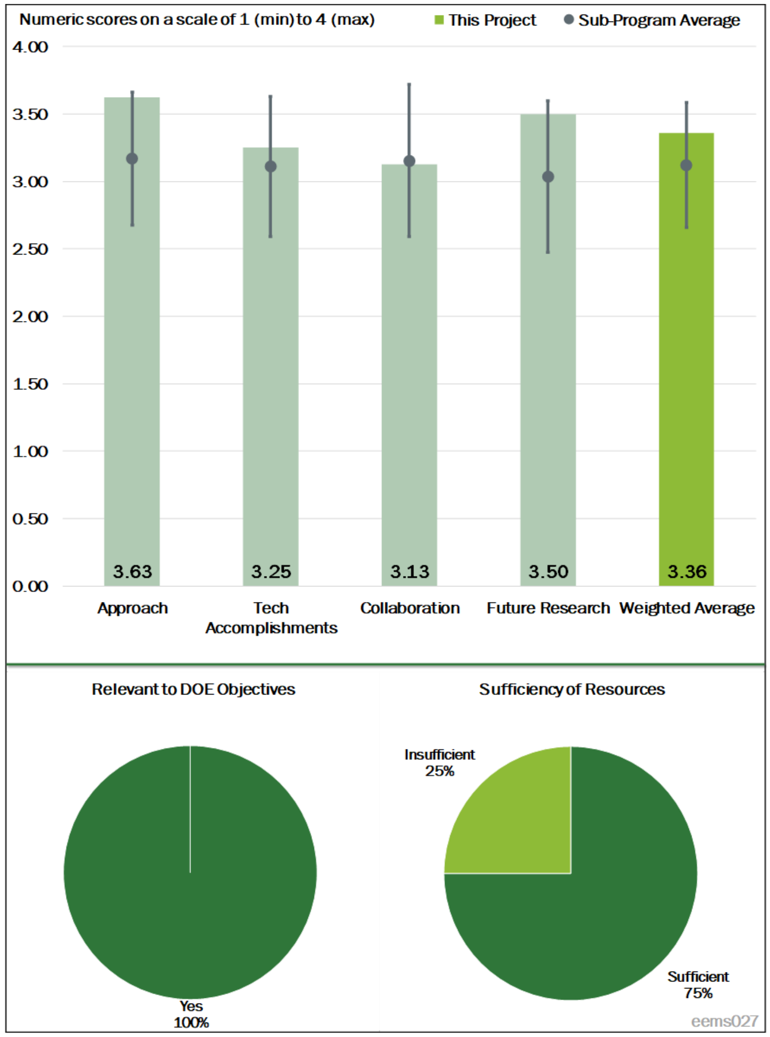

Figure 3-13 - Presentation Number: eems027 Presentation Title: National Scale Multi-Modal Energy Analysis for Freight Principal Investigator: Kevin Walkowicz (National Renewable Energy Laboratory)

Presenter
Kevin Walkowicz, National Renewable Energy Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer commented that the approach is right on track.

Reviewer 2:
The reviewer remarked that the approach is logical and well-defined by the project team in the poster information. The approach is designed to take advantage of existing data sources and partnerships to identify scenarios and quantify assumptions, a valuable use of NREL's connections in the industry. The reviewer said that the project team has identified some logical and useful near-term milestones to guide the work.

Reviewer 3:
The reviewer remarked that this project has excellent potential for actual fleet demonstrations in the future.

Reviewer 4:
The reviewer stated that this project seems sound and follows a reasonable process in terms of evaluation.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer stated that the project has made good work and progress to date.

Reviewer 2:

The reviewer remarked that the accomplishments to date are good building blocks toward the ultimate goal of quantifying modal shift freight efficiency impacts: truck technology efficiency levels, key scenarios, and modeling frameworks. The reviewer stated that the accomplishments show a good balance of work among the laboratory team members. The exploration of multi-modal origin-destination pathways should be useful in understanding how freight will move in the future. The reviewer said that scenarios for future freight technology and freight volumes/modes seem to be appropriate for exploring the parameter space.

Reviewer 3:

The reviewer commented that the project's progress is very good at this stage and shows high potential.

Reviewer 4:

The reviewer remarked that establishing the energy impacts of mode switch and platooning comprehensively will be key to engaging with freight deliverers and cities in terms of seeing these results in action. The reviewer concluded that the project has so far only quantified impacts from a very limited set of freight approaches and still has a long way to go in terms of addressing the universe of applications.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that although improvements are being made from past years, the reviewer believed the poster sessions highlighted some synergies that could be leveraged.

Reviewer 2:

The reviewer remarked that the project team is a nice multi-stakeholder combination of national laboratories, agencies, freight providers, and cities. The project has a good testing ground, and also considers multiple stakeholder views.

Reviewer 3:

The reviewer remarked that there is good collaboration across the project team, but needs more commercial partners.

Reviewer 4:

The reviewer reported that the project team has an extensive list of DOE national laboratory and other partners, including a potential conduit to Columbus Smart City data (Mid-Ohio Regional Planning Commission [MORPC]). The project team is collaborating with the other DOE-funded SMART Mobility Consortium members. The reviewer stated that the team only includes one industry partner at the moment (UPS), so it would be potentially valuable to add to that list (something the team does acknowledge to be the case). This reviewer agreed that additional freight shipping company partners would add to the project. One potential partner/advisor for future freight mode shifts would be the economists/analysts at the American Trucking Associations who publish annual freight forecasts that might add a perspective to better understand the project results.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the data collected will help overall routing and reduce congestion.

Reviewer 2:
The reviewer commented that future research efforts represent a logical pathway to completing the project scope as described by the project team. The results from this future research plan should provide helpful insights to VTO on future freight movement technologies and their impacts.

Reviewer 3:
The reviewer stated that this project will serve as an important basis for vast decisions regarding transportation solutions in the future.

Reviewer 4:
The reviewer commented that the next steps seem reasonable. The reviewer noted that it would also be interesting to see how these tech-enabled freight solutions and mode shift strategies can impact urban freight delivery.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted that this project will produce data to reduce fuel usage congestion.

Reviewer 2:
The reviewer remarked that this project is highly relevant to DOE VTO goals and EEMS goals by facilitating an understanding of freight movements. Freight will be a critical driver of future energy use in transportation and gaining a thorough understanding of the complex potential shifts in freight movement (and the impacts of technology on these shifts) will enable DOE to make better early-stage research decisions.

Reviewer 3:
The reviewer noted that this project is very relevant as it is a high impact area of energy use for the nation.

Reviewer 4:
The reviewer pointed out that addressing freight energy use will be key to making the American freight sector competitive and also efficient.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that given the pace of this project and what has been accomplished to date, it seems entirely possible that the associated budget will not be sufficient to last the rest of the project.

Reviewer 2:
The reviewer stated that this project should consider for more funding to complete project.

Reviewer 3:
The reviewer concluded that the resources appear to be sufficient for the specified work objectives with the inclusion of the (uncosted) data provided by others.

Reviewer 4:
The reviewer noted that looking for more collaboration and reduction of repetition amongst national laboratories would leverage resources more effectively. This is an area of improvement but has more room for improvement.

Presentation Number: eems028
Presentation Title: Developing an Eco-Cooperative Automated Control System (Eco-CAC)
Principal Investigator: Hesham Rakha (Virginia Tech University)

Presenter
Hesham Rakha, Virginia Tech University

Reviewer Sample Size
A total of six reviewers evaluated this project.

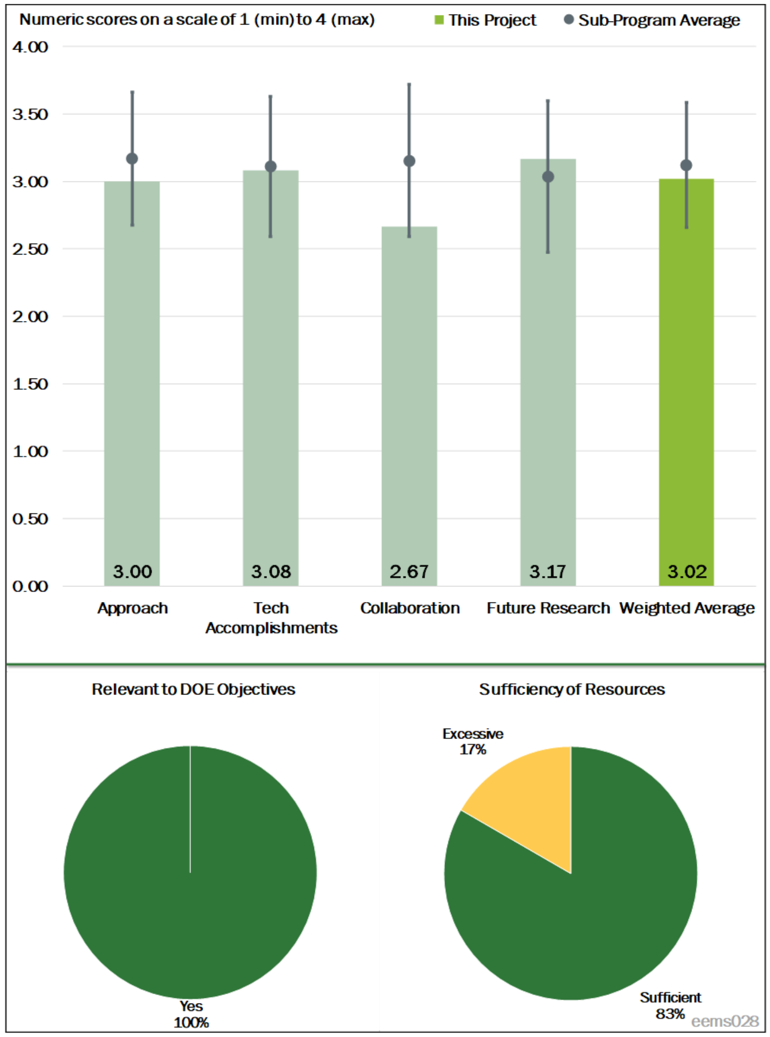

Figure 3-14 - Presentation Number: eems028 Presentation Title: Developing an Eco-Cooperative Automated Control System (Eco-CAC) Principal Investigator: Hesham Rakha (Virginia Tech University)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer remarked that the approach is in line with the objectives.

Reviewer 2:
The reviewer remarked that speed harmonization offers tangible energy impacts. Including automated vehicles (i.e. fully compliant to speed requests from server) should provide even better results. The reviewer said that the work is designed to work over large physical areas as well as multiple powertrains.

Reviewer 3:
The reviewer noted that the project team has developed a systematic two-level control strategy and are executing the building blocks of this strategy.

Reviewer 4:
The reviewer commented that the approach to modeling of individual vehicles is clear and well-designed. The combination of all tasks to a cohesive final project is unclear, particularly the inclusion of the Macroscopic Fundamental Diagrams to regulate system-wide traffic flow. The reviewer stated that the focus on computational speed is appropriate, as it is necessary for use in complex road networks. The presented error in the fuel consumption of an HEV is surprisingly high (10% on slides, 6% said verbally). In particular, the reviewer would expect that the steady state calculation should be independent of regenerative braking and have a very small error. The reviewer noted that specific regions are explored as congested zones, which are potential candidates for perimeter control. When balancing the roadway traffic across all nodes in a network, the reviewer asked how the team will guarantee that fuel consumption and travel time will be reduced, i.e., that the reduction in congestion will not be countered by the additional travel length and driving time.

Reviewer 5:

The reviewer remarked it appears that the project is focused on developing a wide range of models and algorithms; many of them have been previously developed and available. Rather than redeveloping all models (e.g., vehicle energy consumption), the reviewer suggested that the project team consider using existing validated tools so they can focus on the core development of the project (control). The reviewer also recommended that the authors use/reference previous work performed on routing algorithm and highlight the differences of their work.

Reviewer 6:

The reviewer commented that the fundamental building block of any CAV analysis project is the vehicle and propulsion control models and assumptions—both for baseline and CAV scenarios. Rather than using existing trusted high-fidelity models (such as Autonomie), simpler developed models appear to be used, which are likely unable to demonstrate true CAV benefit through driving behavior and powertrain control changes.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that the outline of the tasks and accomplishments is clear and concise.

Reviewer 2:

The reviewer noted that the overall framework is farther along than expected, if indeed the work began in October 2017 and was not started under a previous project.

Reviewer 3:

The reviewer stated that the project team has completed portions of the build blocks of the control strategy such as eco-routing, network monitoring algorithm, Eco-Cooperative Adaptive Cruise Control-I (eco-CACC-I) controller, etc.

Reviewer 4:

The reviewer noted that progress seems appropriate for the short time the project has been funded. Many of the results are finding important parameters of interest for continued research; however, many of the results seem to be too coarse. The reviewer pointed out that, for example, the comparisons of coasting seem overly theoretical and unrealistic. Taking 300 seconds to coast to a stop can be useful as a bounding case, but does not match real-world travel behavior.

Reviewer 5:

The reviewer said that the project is in its early state (6 months), so the reviewer expected that few results will be available. For the Eco-routing task, it is good that each individual vehicle build their own route depending on powertrain. The reviewer stated that the team has selected eight variables to define the routes. It is, however, not clear why or how those variables were selected and if this approach has been validated with high-fidelity models. The reviewer commented that it would also be good for the project team to describe the smoothing procedure that is currently part of the process and whether or not this has been validated with a higher fidelity approach. For 5% traffic, the preliminary energy impact is 6.9% for a 24% increase in travel time. The reviewer would recommend adding some constraints on acceptable time increase as 24% would likely not be acceptable to drivers. Related to vehicle model development and validation, the reviewer would encourage the project team to validate the model under real world driving conditions instead of simply the urban dynamometer driving schedule (UDDS) and highway fuel economy test (HWFET) as those driving cycles are not representative of real world. In addition, if not already the case, the project team should consider proper accessory loads for real-world conditions when estimating vehicle energy consumption. The reviewer recommended the project team consider the uncertainty of their power based model related to CACC. As an example, using a constant value for electric machine efficiency will lead to overestimating the impact of

CACC as the technology will lead to lower operating conditions. Similar comments are valid for conventional, HEVs, and PHEVs.

Reviewer 6:
The reviewer stated that it is difficult to measure the progress of the project due to the short time since inception. However, the reviewer strongly recommended that if high-fidelity vehicle plant models and corresponding controls are not available, the study should focus on the reduction in tractive energy due to driver behavior changes only. The reviewer said that in validating the HEV modelling error—the methodology should be improved to comprehend the statistical divergence in time (or root mean square [RMS]) of the error—not the error of a drive cycle overall. As presented, the reviewer remarked that the total error versus drive schedules is not accurately presented.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that the project has limited partners.

Reviewer 2:
The reviewer noted that the project team has shown good collaboration with Morgan State University and Palo Alto Research Center.

Reviewer 3:
The reviewer remarked that the proposed collaborations seem appropriate, but have not yet started as of this review. The DOE-funded portion is in one research group and is internally coordinated well.

Reviewer 4:
The reviewer commented that Slide 17 describes collaborations, which so far appear to be minimal, however, the project just started. More detail of the work with Palo Alto Research Center and other partners should be evident by next year.

Reviewer 5:
The reviewer said that there does not seem to be any current collaboration other than leveraging existing ones from other projects. The reviewer recommended that the project team reach out to others to reuse existing work rather than trying to redevelop every model internally.

Reviewer 6:
The reviewer noted that the lack of collaboration and coordination with institutions directly will impact the success of this project. The reviewer strongly suggested that the project team collaborate with the members of the SMART Mobility Consortium.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that there are no issues and that the project is in line with the objectives.

Reviewer 2:
The reviewer stated that, while the project is early on, there appears to be a credible path to reasonable results, thanks in part by the clear vision of the project. If successful, the reviewer expects that this project will provide good, defendable estimates for the potential energy improvements of a well-regulated car network.

Reviewer 3:

The reviewer commented that future work includes an eco-routing development, eco-CACC development, integrated eco-cooperative automated control (CAC) system assessment, eco-CAC prototype evaluation, etc. These are all good building blocks for efficient transportation systems of the future.

Reviewer 4:

The reviewer noted that the proposed future research for each task is appropriate. The reviewer commented, however, that risk mitigation (in case some of the research does not work out) was not clearly explained, and it is not clear how all of the tasks will join together into a cohesive product at the end of the project.

Reviewer 5:

The reviewer noted that the project's overall objective and process are very relevant. The reviewer recommended that the project team reach out to re-use existing models and work to make sure the project focuses on the added value.

Reviewer 6:

The reviewer stated that the exact deliverables for the future work are not clearly defined. The reviewer noted that the future work requires the simultaneous creation of systems, controllers, and models, which present a substantial risk for high-fidelity and meaningful results. It leaves the final work subject to large variance as the underlying assumptions mature and the outputs of individual components change due to continued development.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer remarked that the project has importance in the advent of connected vehicles and their impact on traffic routing.

Reviewer 2:

The reviewer commented that ideas on how automation will likely impact energy usage have been given a lot of thought, but rarely with the rigor and specificity shown here. Whether such large-scale regional speed harmonization is likely from a single controlling entity may be difficult, the results here give us some plausible, defendable estimates on energy impacts of a more smoothly operating vehicle transportation system.

Reviewer 3:

The reviewer stated that this project lines up nicely with the energy saving and commute time reduction objectives of EEMS.

Reviewer 4:

The reviewer stated that the project aligns very well with the current DOE objectives by looking at the impact of eco-routing and CACC on the energy at the system level.

Reviewer 5:

The reviewer noted that the project supports DOE objectives with its overarching goals and barriers to overcome; however, the method in which it is being executed may not support DOE objectives efficiently.

Reviewer 6:

The reviewer noted that while the project supports DOE objectives, within EEMS, the focus is on system-level energy use. The project team noted that the vehicles strive toward a Nash equilibrium for energy use, where all vehicles are optimizing their own fuel efficiency. Therefore, it is possible that optimizing each individual vehicle will be less efficient for the system as a whole. Further, the preliminary results presented led to pretty large increases in travel time (20+%). The reviewer said it is unclear if a typical driver will be willing to tolerate such large increases in travel time, which may prevent fuel efficiency gains from being realized.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer had no issues with resources.

Reviewer 2:
The reviewer said that it appears the resources are sufficient to achieve the stated milestones as planned.

Reviewer 3:
The reviewer noted that the resources adequately match the work done so far as well as the proposed future work.

Reviewer 4:
The reviewer stated that the resources are sufficient.

Reviewer 5:
The reviewer noted that the budget seems quite large for a (mostly) university-led project with few high-cost capital needs. However, the project team has made quick progress, so perhaps there is a large team at Virginia Tech. Not having the budget breakdown, the reviewer is not comfortable calling it "excessive." but the reviewer would be curious to see the numbers.

Reviewer 6:
The reviewer stated that it is not clear what the large amount of funding is being spent on in this project. As presented, the focus has been mainly on simulation activities, which do not appear to justify the high cost.

Presentation Number: eems029
Presentation Title: Boosting Energy Efficiency of Heterogeneous Connected and Automated Vehicle (CAV) Fleets via Anticipative and Cooperative Vehicle Guidance
Principal Investigator: Ardalan Vahidi (Clemson University)

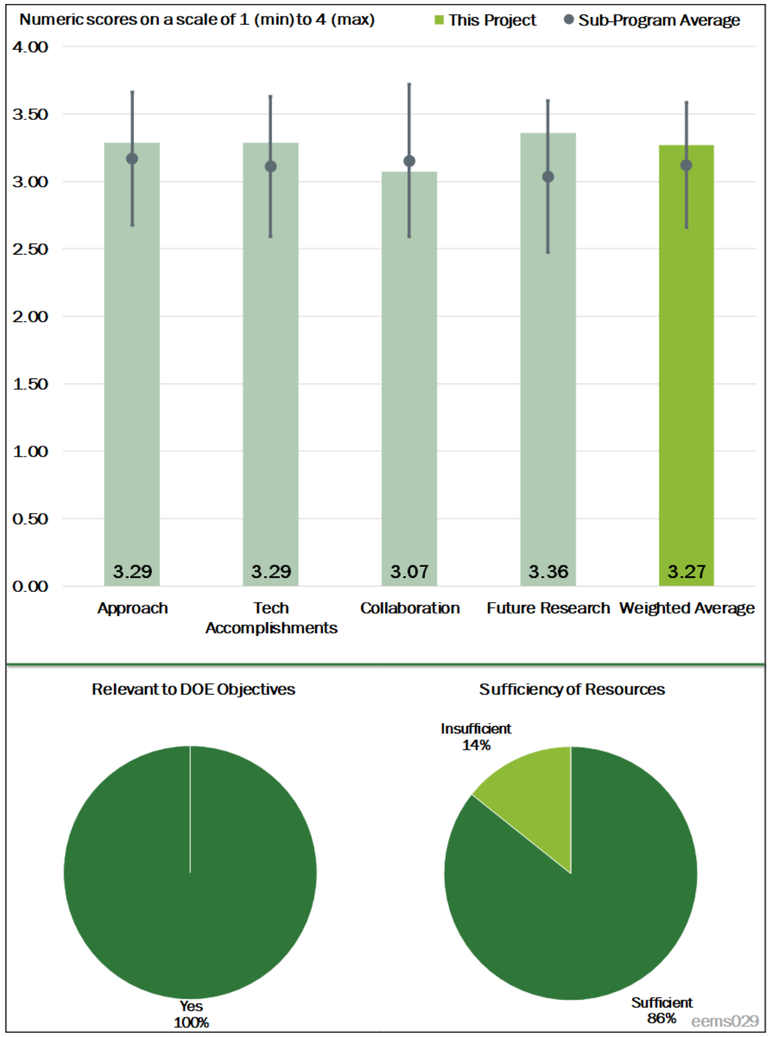

Figure 3-15 - Presentation Number: eems029 Presentation Title: Boosting Energy Efficiency of Heterogeneous Connected and Automated Vehicle (CAV) Fleets via Anticipative and Cooperative Vehicle Guidance Principal Investigator: Ardalan Vahidi (Clemson University)

Presenter

Ardalan Vahidi, Clemson University

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that this is a very logical approach with well-defined tasks and corresponding inputs/outputs. The reviewer said that there are appropriate go/no-go decision points based on realistic metrics. The vehicle-in-the-loop (VIL) work presents increased opportunities beyond typical vehicle/model correlation.

Reviewer 2:

The reviewer commented that the approach is generally excellent. The reviewer suggested introducing metrics to measure smoothness/comfort (e.g., vehicle jerk, proximity to lead vehicle, etc.) as well as safety (e.g., probability of impact x severity under various scenarios).

Reviewer 3:

The reviewer noted that the project team covered all aspects that were relevant.

Reviewer 4:

The reviewer pointed out that the project is well-designed and planned. The PI has a good plan to address technical barriers with a clear focus on ultimately field testing on real-world applications.

Reviewer 5:

The reviewer said that the authors could better specify the objectives of the design of CAV guidance schemes in order to clarify whether there are multiple objectives or energy use minimization is the sole objective.

Reviewer 6:

The reviewer remarked that the simulation of predictive and anticipative algorithms is an important step forward for CAV analysis. The approach has initially omitted position uncertainties/error of CAVs (perfect knowledge) and assumed no communication latencies. The reviewer noted that the positional uncertainties and data latency have the potential to change the simulation results.

Reviewer 7:

The reviewer stated that the project team's approach steps through an appropriate process to build up to "real-world" testing. However, the test track is not "real-world." The reviewer said that it is an important step in the process, but as described, is still limited in terms of capturing and validating the behavior under fully complex scenarios. This will inherently limit the applicability of the output against the desired end state of the objectives. The reviewer stated that more attention should be given to evaluating the effects of the uncertainty in prediction in the pathway and what this means under different contexts. As the PI acknowledged, this needs to be made clearer in terms of how it is accommodated and what the effects are.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the accomplishments are great overall. The prediction algorithm (i.e., where surrounding vehicles will be in the next x seconds) is difficult as the project team mentioned. The reviewer suggested adding/analyzing not just the prediction, but also adding error bars around these predictions as well as some defendable analysis for what constitutes unacceptable results in the real world.

Reviewer 2:

The reviewer noted that the project team is working in line with industry and realistic timelines/goals.

Reviewer 3:

The reviewer stated that the project started last September; however, the project team has made good progress to date and the team is on track to accomplish their milestones.

Reviewer 4:

The reviewer stated that based on the presentation results, the team has made strong progress in the first few months. The project team presented results that showed fuel efficiency improvements for various percentages of CAVS penetration that employed the predictive algorithms described. The reviewer noted that the project team also showed a visualization of the lane prediction algorithm that was useful for communicating the progress.

Reviewer 5:

The reviewer said that the technical accomplishments are very good considering the short time since the work has been started.

Reviewer 6:

The reviewer stated that the work is on schedule and the demonstrated potential for energy efficiency gain is significant. However, the reviewer remarked that the position prediction may not be sufficiently accurate for real-world application (although performance may meet a reasonable benchmark) and the project team noted that latency in communications had yet to be accounted for.

Reviewer 7:

The reviewer stated that the completed work might be technically valid, but it is not clear how it is relevant. Simulation using a test cycle like the US06 (high speed, high acceleration drive cycle) is very rigid and does not capture relevant and important variations and complexity that occur under actual driving conditions. The reviewer said that it is probably an important step for building knowledge, but that is the limit. Improvements in efficiency do not mean much in this context until the underlying principles and behavior can be connected to larger systems or the purpose of the output is more narrowly bounded.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that the presentation showed a clear division of labor across the team.

Reviewer 2:
The reviewer remarked that the project is mainly between Clemson University and the International Transportation Innovation Center (iTiC). It seems that there is a good collaboration between these two organizations. The reviewer stated that it is not quite clear how PTV Group is involved in the project beyond that VISSIM is used. ANL has a very limited participation using Autonomie to estimate energy efficiency.

Reviewer 3:
The reviewer stated the fact that the team is showing energy analysis results indicates the Clemson team has collaborated with the PTV Group to exercise the VISSIM tool to produce initial energy consumption results.

Reviewer 4:
The reviewer noted that the collaboration with identified partners is very good in terms of number and scope.

Reviewer 5:
The reviewer remarked that collaborations are satisfactory but are also quite limited in number (only three) and type (university, DOE national laboratory, international center). The collaboration lacks private sector participation as well as other Federal entities with jurisdiction and expertise in this area (e.g. Intelligent Transportation System Joint Program Office [ITS-JPO]).

Reviewer 6:
The reviewer noted that the project team should have more HD Class 8 truck participation.

Reviewer 7:
The reviewer said that the project team did not adequately cover the collaboration. The presentation included a slide, but a lack of sufficient information was provided to assess the quality of the collaboration. The reviewer stated that this is a problem given the complexity of the work and a lack of incorporation of existing microsimulation that exists either with the partners, or other centers.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the remaining technical challenges are significant and the likelihood of success is unclear, but it is still early in the project.

Reviewer 2:
The reviewer said that the future work seems well-planned. There are well-thought milestones regarding the field testing (including two vehicles) and comparison against the simulation results.

Reviewer 3:
The reviewer noted that the project team covered all areas of concern.

Reviewer 4:

The reviewer commented that the project work plan is logical and includes two major decision points. The reviewer noted that the team has been developing vehicle hardware in parallel to the simulations. One thing missing is feeding the test track results back into simulation which may improve the accuracy of the simulation results/energy analysis.

Reviewer 5:

The reviewer noted that future work plans appears to be organized very logically. The reviewer would appreciate more information on the VIL testbed in order to determine the risks associated with the learning objectives tied to this activity.

Reviewer 6:

The reviewer stated that the future work seems reasonable given the accomplishments from the last year. It may be worth setting up either a formal or informal network of other laboratories using test tracks for CAV work, because it sounded like other laboratories may not have had insurance issues. The reviewer said that perhaps there are some lessons to be learned from others here.

Reviewer 7:

The reviewer commented that the proposal is logical—there is just a lot to do relative to the objective. The reviewer stated that the work seems to progress on an assumption that each task will be accomplished. Given the serial nature of the research proposal, it is unclear how the work can progress if challenges arise or specific results do not yield the requisite outcome.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer stated that the project is examining both physical measurements and modeling space for CAV energy efficiency gains along with the other considerations; therefore, it clearly supports the overall DOE objectives.

Reviewer 2:

The reviewer commented that yes, it is imperative that we find solutions to congestion and the energy use it causes. This will also improve safety for all of the driving public.

Reviewer 3:

The reviewer stated that the project supports DOE objective of petroleum consumption reduction.

Reviewer 4:

The reviewer noted that the project is directly related to DOE’s mission and objectives as it addresses the impact on energy usage of connected and automated vehicles and the implications of different penetrations.

Reviewer 5:

The reviewer stated that the project support DOE’s objective to measure the potential benefits of CAV technologies with regard to energy consumption.

Reviewer 6:

The reviewer noted that yes, this project is very relevant, not only in fulfilling the stated objectives but also in establishing a framework and process for analysis that others could benefit from.

Reviewer 7:

The reviewer said that the project is aligned as an objective with the goal. The project is multi-faceted and complex. The reviewer noted that the concern or risk is that the output will not yield complete results.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the project appears to be making great progress with the allocated resources. The merits of the project would justify additional resources if required.

Reviewer 2:

The reviewer noted that quite a lot of resources have been sent the way of this project, but because the project involves test tracks, heavily instrumented vehicles (including with actuators), the relatively high funding level is probably warranted.

Reviewer 3:

The reviewer stated that the resources look sufficient.

Reviewer 4:

The reviewer commented that there are sufficient resources for the collaborative organizations to achieve the milestones and goals of this project.

Reviewer 5:

The reviewer stated that the project should include HD subject matter experts.

Reviewer 6:

The reviewer noted that the resources are sufficient. Their primary question relates to the overall scope. The reviewer questioned if the project is attempting to do too much and asked if the team should focus on more robust outputs in specific areas as part of a path to build up critical knowledge.

Reviewer 7:

The reviewer noted that the project team commented that test track insurance costs had not be properly accounted for in the initial budget. Because the project team indicated that the insurance was a significant cost, the team should take note of how this money is going to somehow impact the project.

Presentation Number: eems030
Presentation Title: Experimental Evaluation of Eco-Driving Strategies
Principal Investigator: Huadong (Joshua) Meng (Lawrence Berkeley National Laboratory)

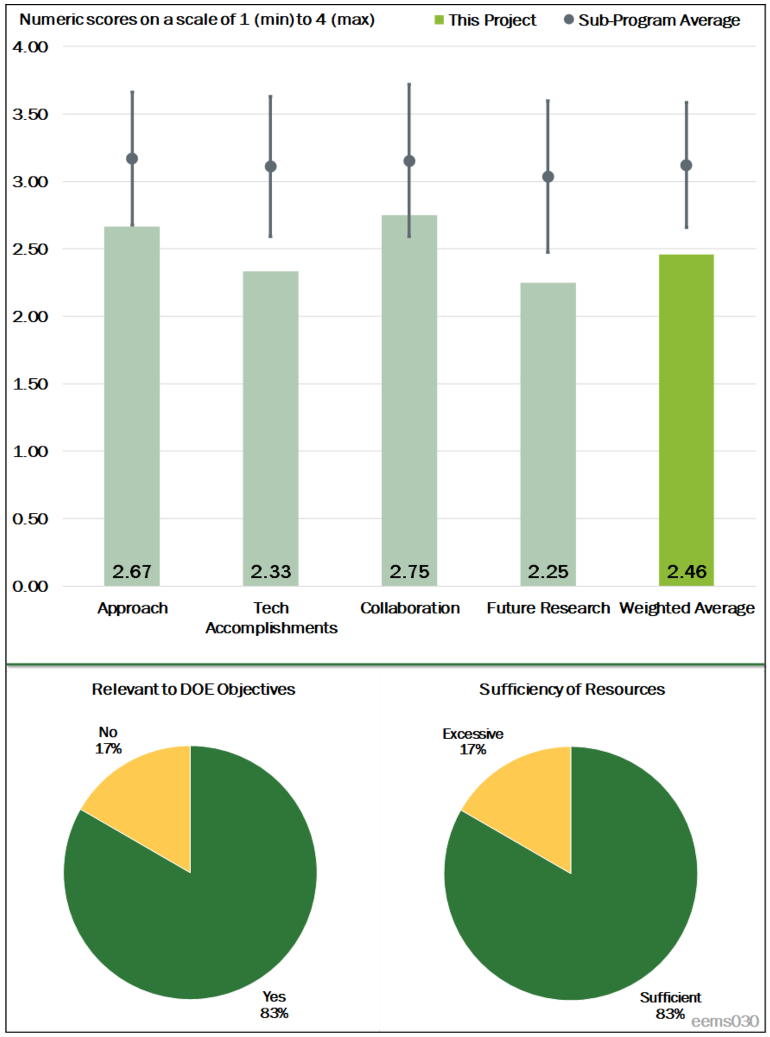

Figure 3-16 - Presentation Number: eems030 Presentation Title: Experimental Evaluation of Eco-Driving Strategies Principal Investigator: Huadong (Joshua) Meng (Lawrence Berkeley National Laboratory)

Presenter

Huadong (Joshua) Meng, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the project one approach of investigating real-world (rather than ideal) benefits of eco-driving is useful. The project two approach sounds reasonable.

Reviewer 2:

The reviewer disagreed with the statement on Slide 18 that "The energy impact of passenger car [CACC] and Platooning can only be determined through physical experiments and should be quantified to highlight two key effects: changes to aerodynamic drag and variations in vehicle speed." The reviewer noted that the bulk of the other projects on display at this AMR justify that modeling has a place within the activities of forecasting CAV and CACC technologies. In terms of model validation or correlation that can occur with the test data, this reviewer would not state that five luxury sport utility vehicles (SUV) would be representative of all the combinations of vehicle interaction within CACC.

Reviewer 3:

The reviewer said that the proposed approach is rather questionable and confusing. The eco-approach and departure has been explored in simulation extensively in the last few years. So, the scope of the 2018 goals seems reductant. The reviewer stated that the PIs should just take the lessons learned in this area, which is well-documented in the literature, and focus on the objectives of FY 2019, which is field-testing. It was not quite clear how this project advances the state of the art.

Reviewer 4:

The reviewer commented that for the first project, the reviewer is okay with the analytical evaluation of eco-driving strategies; however, the reviewer is not sure that given the level of funding, there is much expected from the experimental evaluation of eco-driving strategies.

Once the “real world” is brought in to the picture, there are far too many sources of variability. This coupled with the fact that the project team is trying to evaluate the (small) fuel saving potential over a relatively short driving range (over which not too much fuel is consumed to start with) makes for a hard problem to solve. The reviewer noted that the number of (measured) datasets that will be needed to quantify the fuel saving benefit with a reasonable confidence level would be prohibitive.

The reviewer noted that in light of the fact that the project team would be looking at an experimental evaluation as well (Slide 11), the trajectory planning algorithm appears to be too precise—multiple repeats with the same vehicle would not yield a consistent answer. As the test is repeated, the under hood will likely warm up, and component efficiencies will change, perhaps leading to a different optimum solution. The reviewer said that other factors over which the experimenter has no control could be the weather—wind speed, rain, etc.

The reviewer remarked that for the second project, with five vehicles, if you wish to run a full factorial design of experiments (DoE), you would have 5-120 runs, without repetitions. Assuming at least 3 repetitions (probably more are needed for significance), you would have 360 runs—unless the PI plans to run a fractional factorial DoE. The reviewer noted that there will be variations in fuel consumption between the five vehicles, there will be measurement error involving fuel flow measurements, there will be variation in tire rolling resistance, the weather will change over the course of the tests, there will be the inevitable bugs in the software, etc. The reviewer is not sure that the project team will be able to accomplish everything within budget.

Trying not to be a naysayer, the reviewer acknowledged facing similar situations at work, and there is always the future manager who says that if you put your mind to it you can do it (or something to that effect)—and that may be true—the Laser Interferometer Gravitational-wave Observatory (LIGO), of which the reviewer is a huge fan, is a prime example—and it richly deserved the Nobel Prize. However, it also needed, if the reviewer remembers right, about $600 million. So, according to the reviewer for this project to yield any conclusive results, it needs a much stronger (test) plan, quantification of the sources of variability, and input from a statistician to ensure that the overall (statistical) methodology is sound—perhaps it exists and the project team did not share the complete details. If so, this reviewer stands corrected.

Reviewer 5:

The reviewer noted that two projects were presented, however, it was not very clear what the approach is between the two.

Reviewer 6:

The reviewer remarked that there are two parts to this project. The reviewer stated that the second half was confusing. Platooning in urban environments at city speed has minimal drag reduction benefits relative to energy for accelerations, but appeared to be conveyed as a major factor. The reviewer noted that it was unclear what the value of the objective was based on the presentation (as given). The reviewer asked if for part one the objective is to evaluate under real-world the total system benefits, or the individual benefits without measuring the impact on other vehicles or throughput of the system.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the projects have just begun, so technical accomplishments are limited. The reviewer noted that there are no clear impediments to progress.

Reviewer 2:

The reviewer remarked that both sub-projects in this item are just beginning. It is therefore difficult to place a rating on this question.

Reviewer 3:
The reviewer noted that the project started recently but there has been some progress. It does not seem, however, that there is a clear focus on what the outcome should be.

Reviewer 4:
The reviewer referenced prior comments and stated that because the project just started in March 2018, there is not a lot of progress to share. However, there is ample time to refine the project scope and method to yield useful results.

Reviewer 5:
The reviewer commented that the project lacked clarity on what exactly has been done to-date as well as the next steps.

Reviewer 6:
The reviewer noted that the work lacks clarity and does not appear to advance the state of the literature or knowledge very much. This is especially true for the simulation part. The reviewer commented that the project team needs to more clearly articulate the objectives and purpose. This was partially done during the Q&A but was not sufficient and raises concerns over the clarity and focus of the work and how the output may be used.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer noted that per Slide 23, the project team looks to be working with a good set of relevant partners. INL is a good partner and has a good history in being successful with this type of work.

Reviewer 2:
The reviewer commented that it seems that this is a collaborative project between LBNL and Saxton Lab (by providing the cars). The reviewer stated that INL’s role should be better clarified.

Reviewer 3:
The reviewer commented that perhaps the project team could benefit a great deal from discussions with the Advanced Powertrain Research Facility (APRF) team—understanding measurement variability, accuracy of controller area network (CAN) signals, etc. are critical to the success of this project. Any variability that the LBNL team sees in its testing can only be worse than what the APRF team has seen on the dynamometer.

Reviewer 4:
The reviewer noted that this work needs a precise plan on what needs to be achieved for the two respective projects.

Reviewer 5:
The reviewer remarked the presentation showed the roles of team members; however, actual collaborations remain to be seen.

Reviewer 6:
The reviewer stated that the collaboration appears to exist for the sake of collaboration. It does not appear to add any value, and probably only adds complexity and cost to the project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer referenced prior comments and remarked that the work is just beginning.

Reviewer 2:
The reviewer remarked that this project is a little weak on the details.

Reviewer 3:
The reviewer stated that the planned work for next FY is to be determined. The project team is awaiting funding availability. The reviewer said that this is a concern as to the value of the project.

Reviewer 4:
The reviewer commented that the presentation did not cover this topic.

Reviewer 5:
The reviewer did not believe that using five luxury sedans driving together at various speeds and distances will give a robust surface to use in the modelling part of this project. On-road fuel estimates, climate, and other vehicle operating variability will all add to potential inaccuracies in the fuel prediction surface.

Reviewer 6:
The reviewer noted that there is no clear plan for future work but rather some generic objectives.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer remarked that this project supports DOE objective of petroleum consumption reduction.

Reviewer 2:
The reviewer noted that the research is trying to address the question of forecasting future fuel use (energy use) should connected vehicles become adopted.

Reviewer 3:
The reviewer stated that the project is relevant to DOE's mission and objectives as it addressed the energy impact of connected and automated vehicles.

Reviewer 4:
The reviewer said that the eco-driving strategy could definitely be considered a part of the EEMS program, although the coverage of this project is rather narrow.

Reviewer 5:
The reviewer remarked that the project itself has value but was unsure it is being executed properly.

Reviewer 6:
The reviewer noted that the objective is poorly articulated and at too high of a level to add or have confidence that it will add value. The reviewer concluded that as presented, this is a poorly formulated project.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the resources could become an issue depending upon funding.

Reviewer 2:

The reviewer remarked that the resources look reasonable.

Reviewer 3:

The reviewer stated that the scope of this project in terms of the overall EEMS goal of improving Mobility Energy Productivity (MEP) is relatively narrow, and the funding should be sufficient.

Reviewer 4:

The reviewer commented that $700,000 in funding should be enough to perform a significant amount of data collection. The modeling portion appears to be much less resource intensive than the projects working RoadRunner and Polaris, so the funding amount appears proportionally correct.

Reviewer 5:

The reviewer stated that it seems that the project has more than the required resources to achieve the milestones and objectives as they are stated.

Reviewer 6:

Although funds are sufficient to conduct the work, the value of the work is the bigger question posed by this reviewer.

Presentation Number: eems031
Presentation Title: Traffic Micro-Simulation of Energy Impacts of CAV Concepts at Various Market Penetrations
Principal Investigator: Xiao-Yun Lu (Lawrence Berkeley National Laboratory)

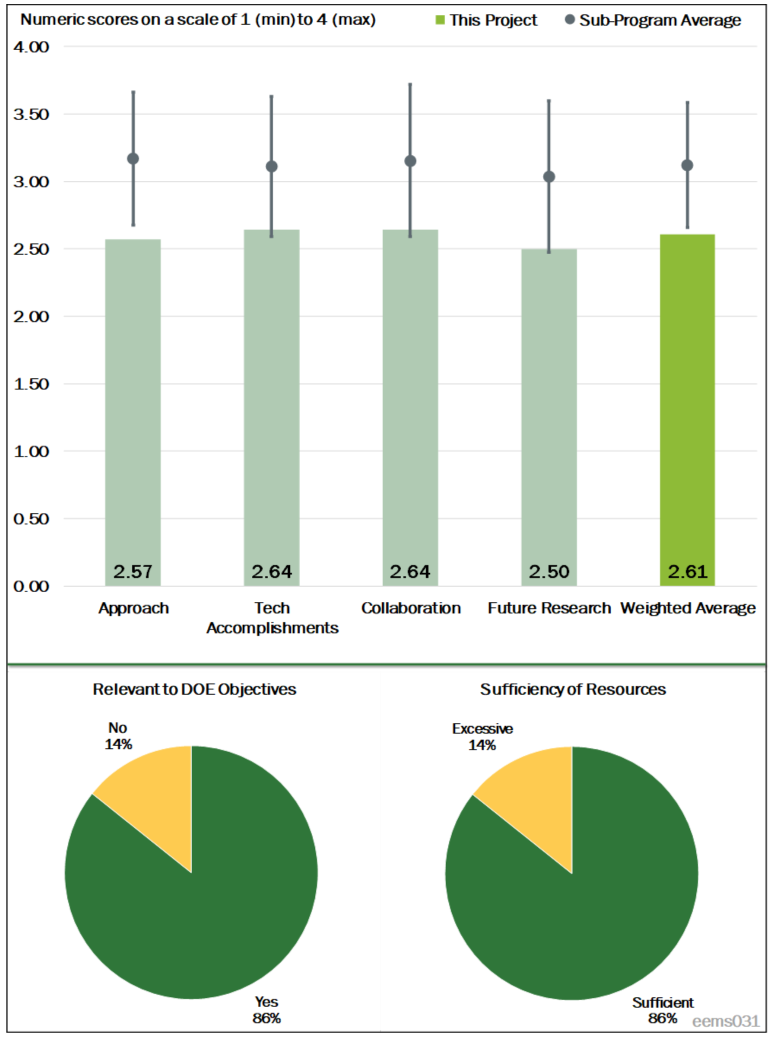

Figure 3-17 - Presentation Number: eems031 Presentation Title: Traffic Micro-Simulation of Energy Impacts of CAV Concepts at Various Market Penetrations Principal Investigator: Xiao-Yun Lu (Lawrence Berkeley National Laboratory)

Presenter
Xiao-Yun Lu, Lawrence Berkeley National Laboratory

Reviewer Sample Size
A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer stated that the work is well-vetted within the DOE research community, drawing from past studies and collaborating with other researchers. This project is well-suited to address the remaining challenges, which are still significant with respect to the realistic incorporation of active traffic management (ATM) features within a mixed CAV and manual driven vehicle environment, in particular.

Reviewer 2:
The reviewer liked the concept and the approach, but is not thrilled with the reporting of the results—hence, a satisfactory.

Reviewer 3:
The reviewer had difficulty really understanding the project’s approach. The speaker was unfortunately not a great communicator.

Reviewer 4:
The reviewer commented that the FY 2017 energy modeling approach relies on the motor Vehicle Emission Simulator (MOVES) model curve fit for fuel consumption. Given the dynamic nature of the system being simulated, the reviewer asked if this approach is sufficiently detailed. This point is apparently being addressed in FY 2018.

Reviewer 5:

The reviewer stated that the modeling approach does not seem to align well with the objectives. The idealized and oversimplified control constraints do not lead to useful output, and the MOVES model is probably not the right simulation tool based on how it manages inputs.

Reviewer 6:

The reviewer commented that the approach taken in this project is confusing and raises several questions. It seems that there is an overlap with the project EEMS030. It is not clear who the distinct contributors of these two projects are. The reviewer noted that there are no technical details about the different scenarios used, e.g., vehicle coordination in merging, speed harmonization, etc. On the same note, these scenarios have presented in other EEMS projects. The reviewer asked how this project is different from the other efforts. It seems that the project focused on simulation while it should be clearly focusing on field testing and validation in real-world scenarios.

Reviewer 7:

The reviewer noted that the research focuses on simulating the effect of CACC vehicles at different market penetration rate. The author mentioned that the CACC vehicles are operating in an environment when various Traffic Management technologies exist. The reviewer commented that the human model part of this work should be explained more clearly. For example, this reviewer inquired about how the vehicles interact with other vehicles when they are not CACC, how they interact with ATM systems, and whether the project team has real data to confirm these human behavior models as accurate. The "simple vehicle following model" was built to describe the CACC vehicle behavior. The reviewer noted that equations were given, but observed no validation or justification regarding whether or not these simple models are accurate enough. The reviewer asked if time delay/lag in the powertrain was considered as it was not clearly shown in the equations. The reviewer also asked if the desired CACC truck T-gap of 1.2 or 1.5 seconds is safe and what would happen if the lead passenger car braked hard.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that carefully managed progress toward the objectives of the work appears evident in the project team's presentation and explanation of the progress achieved.

Reviewer 2:

The reviewer noted that the project appears to be progressing well for the FY 2018 tasks. Using a 16-month schedule is somewhat confusing; it appears FY 2019 work is also shown.

Reviewer 3:

The reviewer acknowledged the possibility of misunderstanding the work, but commented that the overall project was confusing and not well presented or explained. Either the results are accurate, but not precise, or they are not. They cannot be directionally correct and not accurate. Directionally correct is accurate, just not precise. The reviewer said that if the project team cannot sufficiently explain what is happening, and do not understand what or why, it is hard to have confidence in the output and progress of the work.

Reviewer 4:

Although it is great that a real highway corridor is modeled, this reviewer observed no "model validation" work. It was not explained why fuel economy of cars reduces with higher CACC truck penetration rate. The reviewer remarked that it was also not explained why a CACC truck should be used at intersections—they should operate only on highways.

Reviewer 5:
The reviewer commented that it looks like the project team made technical results, but they do not jump out in the documents nor in the presentation. The accomplishments need to be simply stated.

Reviewer 6:
The reviewer commented that the project team has made some progress to date toward achieving their milestones and goals of the project; however, the results are questionable and not well-justified.

Reviewer 7:
The reviewer stated that the graphs (e.g., on Slide 12) were both confusing and contradictory with other slides. The reviewer did not believe in being the only reviewer who was somewhat lost. There was also some concern that MOVES was not an appropriate model to use in microsimulations such as this. The reviewer pointed out that the project team also claimed that adaptive cruise control (ACC) only looks one vehicle ahead versus how humans (and perhaps CACC) have knowledge of multiple vehicles around or ahead. While this is mostly true today, this assumption is likely not valid in the future, even for ACC, since sensors and data processing keep advancing, and it is not inconceivable for these non CACC systems soon gaining the ability to see multiple vehicles ahead just as human drivers do (e.g., Subaru EyeSight with more advanced image processing).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that the extent of collaboration and coordination with other DOE research national laboratories and research projects is evident from the project team’s presentation.

Reviewer 2:
The reviewer stated that despite logos from five national laboratories appearing on the title slide, the actual collaboration seems minimal. From Slide 16, the actual coordination was really a limited correspondence with ANL (Aymeric) who delivered some code.

Reviewer 3:
The reviewer stated that the main collaboration is with ANL involving data sharing and Autonomie usage. As described, it sounds like an arms-length relationship. The reviewer commented that a closer collaboration (e.g., for the investigation into using Autonomie instead of a MOVES-based model) might be beneficial.

Reviewer 4:
The reviewer stated that much information was given on the feedback and coordination. Autonomie is generally well-received and has achieved a good level of robustness, buy-in, and support from industry. The reviewer noted that it is not clear what feedback this project has received from Aymeric or others, or if the researchers understand what was provided.

Reviewer 5:
The reviewer said it seems there is a collaboration between the national laboratories participating in this project. It is not quite clear though what the role is of the University of California-Berkeley.

Reviewer 6:
The reviewer commented that it is not clear how the research work was done at various partner sites and how the team is collaborating.

Reviewer 7:
Again, with collaboration, albeit only LBNL, University of California-Berkeley, and ANL, the reviewer would have liked to see a RASIC (responsible, approves, supports, is informed, is consulted) chart as to what coordination is really happening. The project’s total funding was $390,000, and this reviewer asked who received funding and what was really done with the funds.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the FY 2019 proposed work will help to refine results obtained so far.

Reviewer 2:

The reviewer stated that there should be clear effort in model validation and establishing "the reference," i.e., non-CACC fuel economy behavior, including how human driver interacts with ATMs.

Reviewer 3:

The reviewer pointed out that the project team listed next steps, but did not explain how the team will further the objective, or provide sufficient detail on the actual work and methodology. The project team says what they will do, but not how, or why.

Reviewer 4:

First, according to the reviewer, this project was not evaluated last year. There are results for the 2017 calendar year, but they were not clearly stated. Then there is some work for the 2018 calendar year, but it was not clearly stated. The reviewer would like to see the team "quantify" its results before going further.

Reviewer 5:

The reviewer stated that the progression of operating environment complexity and scale shows attention to adequate, achievable steps of analysis. The source of empirical data noted during the question and answer period concerning the impacts of manually operated vehicle imposing dynamic perturbations to the ACC and CACC operations was important. The reviewer stated that this should be noted in reports and the objective of achieving an ability to model such perturbations and the system recovery in future simulations should be noted. This may impact further the rate at which energy efficiency goals are realized as the percentage penetration increases and manually operated vehicles assume a safe AV response to aggressive driving maneuvers.

Reviewer 6:

The reviewer commented that the future work in FY 2018 is rather generic. There should be a clear focus and details on field testing and experimental validation.

Reviewer 7:

The reviewer remarked that it is very difficult to assess future research plans (primarily Slide 18 and 20) without a better understanding of the overall project state. These slides do not articulate what will truly be gained by completing this work.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer stated that the project supports the energy consumption reduction mission. It investigates emerging technologies that can have an impact on reducing vehicle fuel consumption.

Reviewer 2:

The reviewer remarked that the project does support the overall DOE objectives in that it is bringing a dose of real-world insight into energy efficiency conclusions as CAV technology begins to increase in percentage penetration in what will remain an operating mix heavily weighted toward manual vehicle operations for the next few decades.

Reviewer 3:
The reviewer stated that the project is relevant to DOE's mission and objectives as it addresses the energy impact of different technologies and approaches of connected and automated vehicles.

Reviewer 4:
The reviewer remarked that as best as can be ascertained, this project does examine fuel efficiency resulting from various traffic scenarios, so yes this is relevant to DOE objectives.

Reviewer 5:
Per the reviewer, this reviewer cannot clearly and succinctly tell if this project supports DOE results with its current report-out.

Reviewer 6:
The reviewer commented that while the work indeed studies the "system," beyond just simulating vehicles, there is no clear effort towards validating the behavior of ATMs, including how other vehicles interact with these ATMs. Therefore, it is not clear the developed model is useful.

Reviewer 7:
The reviewer commented that this work, in its current state, lacks clarity. The objectives are good. The reviewer stated that there needs to be a better explanation of the work and how the output fundamentally answers questions and generates useful actionable knowledge.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the project is drawing effectively from other work and leveraging the available resources across DOE national laboratories. Resource deficiency may become evident as time goes on because the most challenging part of the work (developing simulations that reasonably represent the mixed operations of CAV and MOV traffic) is ongoing.

Reviewer 2:
The reviewer said that the overall funding level is pretty low, but for simulation-only research it should be enough.

Reviewer 3:
The reviewer commented that the project has sufficient resources to accomplish the milestones and goals.

Reviewer 4:
The reviewer stated that the funding for FY 2018 is adequate. Should the project continue, FY 2019 work shows no funding allocation.

Reviewer 5:
The reviewer stated that the funds are sufficient; however, how the work is being conducted is not sufficient.

Reviewer 6:
The reviewer reiterated that the project received $390,000, and asked what the team really accomplished. Put it in energy terms, in dollar terms, etc. The reviewer suggested reading the University of Chicago's book *Freakonomics* and report out as such.

Reviewer 7:
The reviewer commented that without a better defense or justification of this work, it is difficult to see the rationale for funding this further.

Presentation Number: eems032
Presentation Title: Evaluating Energy-Efficiency Opportunities from Connected and Automated Vehicle (CAV) Deployments Coupled with Shared Mobility in California
Principal Investigator: Matthew Barth (University of California-Riverside)

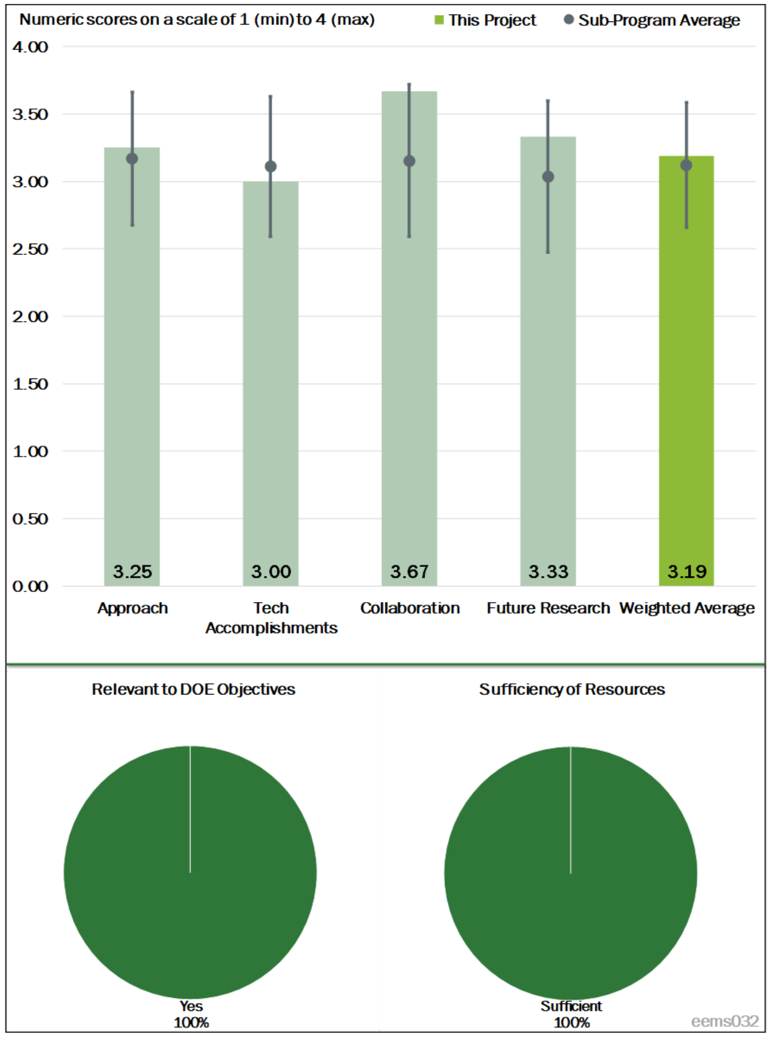

Figure 3-18 - Presentation Number: eems032 Presentation Title: Evaluating Energy-Efficiency Opportunities from Connected and Automated Vehicle (CAV) Deployments Coupled with Shared Mobility in California Principal Investigator: Matthew Barth (University of California-Riverside)

Presenter
Matthew Barth, University of California-Riverside

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer stated that the project addresses critical questions and barriers by quantifying the energy impact of disruptive technologies. The approach is solid with a balanced list of tasks including, simulation, field testing, and using experimental data. The reviewer commented that the PI has also considered a solid plan to address eco approach and departure in cases of different penetration and when multiple vehicles are involved. The project significantly advances the state of the art.

Reviewer 2:
The reviewer commented that this is a strong approach from an accomplished research team. Efforts to date mostly focus on data gathering. The reviewer said that the model framework makes sense but still needs significant work to add detail. The project especially needs more work on behavioral elements such as value of travel time and other hedonics.

Reviewer 3:
The reviewer said that the project can only achieve its objectives if it is able to collect far more, and better, data than reported. Slide 5 indicates that there are no automation real-world data available to the project. The reviewer noted that CAV data sources on Slide 8 are primarily focused on safety application, with no plan described for determining energy impacts. MaaS data described on Slide 10 are short on details, and several other researchers are already studying the data from NYC Taxi and RideAustin. The reviewer stated that crowd-sourced data from shared mobility applications mentioned on Slide 13 is not detailed. The reviewer is

concerned that there is no clear plan to fill the data gaps needed for this work to produce significant new results.

Reviewer 4:

The reviewer stated that overall the approach is good. However, the reviewer asked how the project will factor in mode shifts (to transit, to biking, to walking, etc.). It is not entirely clear if the focus is mainly on energy impacts from mode shifts or from the potential for shared vehicles to be electric. The reviewer asked if the project touches on the potential for increases in electric vehicles does it address the needed charging infrastructure as a barrier.

Reviewer 5:

The reviewer stated that the work to obtain data from real-world and simulation modeling across a range of international sources is very, very good. The remaining challenge of obtaining adequate data from transportation network companies (TNC), which operate the large majority of shared ride services, is daunting because of the proprietary nature of these data. However, the reviewer said that the project team is mining other sources in place of Uber/Lyft data. The reviewer asked how the team will incorporate empty vehicle movements into the analysis, when most travel demand and traffic assignment modeling tools do not include these vehicles. Slide 10 makes simple reference to this factor, but the presentation gave no details or discussion. The reviewer concluded that for the results to be truly representative of future scenarios with a proliferation of shared-ride trips, the empty vehicle movements of these fleet operations (as well as potentially the private vehicle empty movements over the long term) must be modeled in as rigorous a manner as other travel classification/trip purpose trips.

Reviewer 6:

It is good to study in small chuck, and not proposed a vast and incompletely scope, like the list on Slide 8. The reviewer struggled with Slide 9 in that it lists as an accomplishment the collection of results from other studies. The reviewer concluded that the proposed future work lists most of the items in this presentation that will become useable information.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that this project appears to be on schedule per the status presented.

Reviewer 2:

The reviewer stated that the project team has made significant progress to date and it seems they are on track to accomplish their milestones and objectives of this project.

Reviewer 3:

The reviewer stated that, as described on the previous question, the difficulties for gaining data are noted, but few clear plans are given to gain the necessary data.

Reviewer 4:

The reviewer noted that Slides 9 and 10 are the only ones that list any types of results, and they are from previous studies. At 30% complete, the bulk of the useful results are still to be generated.

Reviewer 5:

The reviewer remarked that the project seems to be struggling a bit with the data gathering portion—many of the sources mentioned have been used before, or targeted by other research efforts without success. The project team should identify firm data partners soon if data will be a roadblock—and it is usually the biggest challenge to these sorts of projects.

Reviewer 6:

The reviewer pointed out that the modeling objectives appear daunting to accomplish within the next year, when the framework of incorporating multiple different modeling platforms is addressed. The reviewer asserted that it is feasible to accomplish this within the schedule and budget, if the work is efficiently managed and the modeling framework proves to be adequate for the modeling/simulation tools selected.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that there are good partners, especially in California.

Reviewer 2:

The reviewer commented that the collaborative effort is very high, as shown by the excellent data collection from a number of past studies and data collection efforts.

Reviewer 3:

The reviewer stated that there is a well-established collaborative relationship between the University of California, Riverside and NREL.

Reviewer 4:

The reviewer remarked that per Slide 12, the project team appears to be working with a good set of relevant partners. The reviewer believes that there is some room for improvement if an OEM could be engaged. There is also room for improvement if the project team researches whether there are any industry standards that are being framed that could affect the final results of the work.

Reviewer 5:

The reviewer noted that the project appears to have good breadth of collaborators. The presentation could be more explicit on how and when the collaborators are contributing.

Reviewer 6:

The reviewer said that the set of collaborators are fine choices for this topic, but little was explained about how the interactions are closing the data gaps mentioned before.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the project team has a good plan moving forward to FY 2018. The team should explicitly link the proposed tasks and objectives to the milestones of the project.

Reviewer 2:

The reviewer concluded that the next steps make sense, but again may be challenged by data availability.

Reviewer 3:

The reviewer stated that the presentation did not convincingly address the plan to collect the needed data. It is hard to see how the future goals of the project can be met without progress on a data collection plan.

Reviewer 4:

The reviewer commented that this project could be strengthened by adding in how the resulting product will be put into practice or use, what it will look like, and whether they will get end-user input.

Reviewer 5:
The reviewer said that, assuming success and good correlation to the test data, the list of proposed future work appears to be relevant to potential energy savings.

Reviewer 6:
The reviewer remarked that the scale of modeling that is anticipated in the future research (Slide 14) is very large, and there may be a decision tree needed to scale back some aspects—depending upon how the incorporation of modeling tools into the modeling framework (Slide 11) plays out. The reviewer concluded that it is better to accomplish a little less and do it thoroughly than attempt too much and end the work with incomplete results at any level.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented that the project is making a direct contribution to DOE/EEMS goals.

Reviewer 2:
The reviewer stated that the topic is very relevant to the goals of EEMS, especially issues relating to energy efficiency of MaaS transportation.

Reviewer 3:
The reviewer noted that the research is trying to address the question of forecasting future fuel use (energy use) should connected vehicles become adopted.

Reviewer 4:
The reviewer stated that the focus on shared-ride services as a key and integral part of the travel demand and modal transport operations is very important, because this will show key information about vehicle occupancies and empty vehicle movements as an inherent aspect of their use. This aspect of typical regional modeling and transportation planning is very lacking in typical metropolitan regions.

Reviewer 5:
The reviewer concluded that this project is relevant to DOE's mission and objectives as it evaluate energy efficiency opportunities from large-scale deployments of connected and automated vehicles.

Reviewer 6:
The reviewer stated that the relevance to EEMS is clearly articulated in the presentation.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that the resources seem at least sufficient for the project based on progress to date.

Reviewer 2:
The reviewer said that the $1.1 million in funding should be enough to perform a significant model development and data collection.

Reviewer 3:
The reviewer noted that the financial resources and the laboratory teams are quite sufficient to accomplish the objectives, but with consideration of the comments to the other questions.

Reviewer 4:
The reviewer stated that the project has sufficient resources towards accomplishing its goals.

Reviewer 5:

The reviewer pointed out that resources appear sufficient based on what was presented.

Reviewer 6:

The reviewer noted that the resources are sufficient given the plan as described. The reviewer stated, however, that too little is shared about the methods to get the needed data. Collecting data can be expensive, but also needs a plan, which was not clearly shown.

Presentation Number: eems033 Presentation Title: Truck Cooperative Adaptive Cruise Control/Platooning Testing: Measuring Energy Savings and Aerodynamic Interactions Principal Investigator: Xiao-Yun Lu (Lawrence Berkeley National Laboratory)

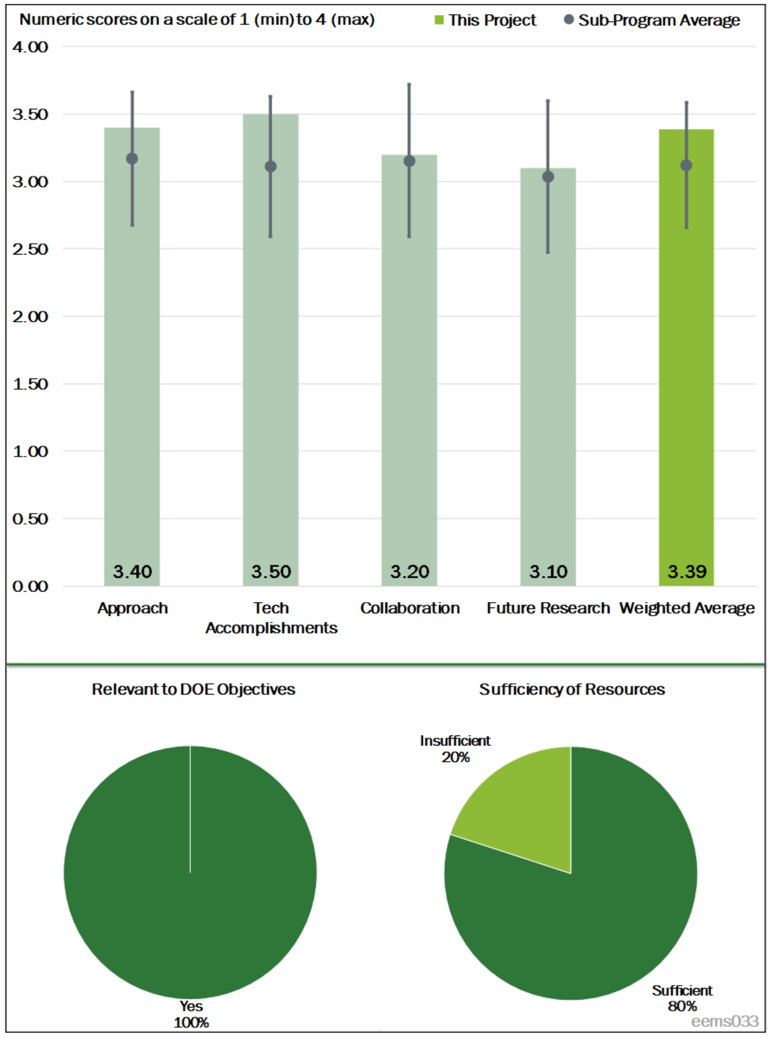

Figure 3-19 - Presentation Number: eems033 Presentation Title: Truck Cooperative Adaptive Cruise Control/Platooning Testing: Measuring Energy Savings and Aerodynamic Interactions Principal Investigator: Xiao-Yun Lu (Lawrence Berkeley National Laboratory)

Presenter

Xiao-Yun Lu, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the project has a very good approach and all barriers were addressed.

Reviewer 2:

The reviewer stated that the project has an excellent approach using combined real-world measurement and sensor data to validate modeling. The range of tested gaps is very impressive and leads to new results. Based on the discussion, some progress is still needed to integrate these. The reviewer pointed out that the experimental work is still well-designed.

Reviewer 3:

The reviewer commented that this is appropriate for this stage of the project.

Reviewer 4:

The reviewer commented that the approach to the work is straightforward and will produce the desired understanding of truck platooning energy effects. The team has chosen an appropriate truck loaded weight (65,000 lbs.) that aligns with DOE SuperTruck parameters and average loaded weights for trucks of this type, so the results should be applicable to the “average” truck and operator. The reviewer pointed out that the team has established an appropriately broad range of speeds, following distances, configurations (two-truck and three-truck), and maneuvers that will help define the energy savings parameter space for platooning. The project team is using the appropriate standardized Society of Automotive Engineers (SAE) fuel economy testing processes as well.

Reviewer 5:

The reviewer pointed out that the project is well-designed; however, it could be strengthened by explicitly addressing how the industry could benefit from the results and how the results will be conveyed to the industry and put into practice.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that these are world-leading results on energy savings from truck platooning.

Reviewer 2:

The reviewer stated that the project has very good accomplishments and discovery. The reviewer commented that this work should continue.

Reviewer 3:

The reviewer noted that the team has accomplished quite a bit in the year since the project started. The fuel savings behaviors of the trailing trucks are interesting and the team has done a good job of clarifying the complex set of effects by truck. The reviewer said that the team has also done enough testing (in 2016 and 2017) to be able to show the effects of control algorithms on fuel savings potential (an aid for those designing these systems for efficiency). Quantifying the effect of the LD vehicle cut-ins and LD vehicle lead scenarios is important—the fact that these cut-ins can reduce the overall energy savings may be helpful for technology developers to understand and mitigate. The reviewer commented that the correlation between CAN bus fuel consumption estimates and SAE testing was helpful to show—this may help with confidence in results of future on-road testing using CAN bus fuel consumption data collection efforts.

Reviewer 4:

The reviewer remarked that this is appropriate for this stage of the project.

Reviewer 5:

The reviewer pointed out that the project seems well on track to the presented schedule and goals.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the project has very good collaboration and made a good move bringing in Transport Canada.

Reviewer 2:

The reviewer remarked that the project has excellent international collaboration, but could use better connections to research in related disciplines (e.g., modelers) to help use micro-scale results and sensor data.

Reviewer 3:

The reviewer said that the overall cooperation is good and the team has leveraged Transport Canada interests and funding to further both U.S. and Canada research goals. The project team showed good distribution of tasks among National Research Council of Canada (NRC) and several DOE national laboratories. Although unmentioned by the team in the presentation, the reviewer believed that this project took advantage of platooning-equipped trucks from a previous project with DOT, Volvo, and several other partners, and recommended that the team note this if it is allowable.

Reviewer 4:

The reviewer pointed out that collaboration among the various labs has improved but the project has more potential to leverage completed work.

Reviewer 5:
The reviewer stated that the project appears to have good collaboration and use of partners in carrying out the tests and analyzing the data. It is not clear whether or not partner feedback was used in developing the research goals and approach before the study moved forward. The reviewer pointed out that this upfront, initial feedback can be beneficial down the line.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that proposed research is needed to complete this important study.

Reviewer 2:
The reviewer questioned the focus on intersection work, which seems relatively unrelated to the progress made here. Other approaches, such as working on optimal tractor-trailer design for platooning, could be considered in addition or in place of this work.

Reviewer 3:
The reviewer commented that the future work plan involves useful extensions of the existing work plan (exploration of fuel savings at signalized intersections and real world highway driving). The specific plans are reasonable for achieving the desired goals assuming that the one year left in the project duration will be sufficient to complete these tests. The reviewer observed that the on-road testing is probably the highest-risk activity and went on to ask if it should be done in one of the previously-defined automated vehicle testing corridors.

Reviewer 4:
The reviewer remarked that this is appropriate for this stage of the project.

Reviewer 5:
The reviewer reiterated that this would be strengthened if the future research factored in how the results would be transferred to the industry, users, etc.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented that, yes, this will save fuel and improve road safety.

Reviewer 2:
The reviewer mentioned that the project directly supports DOE / EEMS objectives, especially in the key area of freight.

Reviewer 3:
The reviewer stated that truck platooning is receiving quite a bit of interest in the commercial truck market and understanding of the energy-related effects of this technology is very relevant to DOE national energy efficiency goals. It will be important to understand the impact of these technologies on the overall efficiency of the individual trucks using these systems as the interactions between trucks can be complex. The reviewer pointed out that physical testing of systems in real-world environments is a very good way to understand these effects. The efficiency gains that will drive uptake of platooning technology supported by DOE and others must be clearly understood to convince MD/HD truck buyers to adopt these systems.

Reviewer 4:
The reviewer commented that this is appropriate for this stage of the project.

Reviewer 5:
The reviewer remarked that, yes, the project specifically addresses the potential fuel efficiency benefits of truck platooning.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that more funding is needed to produce all of the desired results.

Reviewer 2:
The reviewer remarked that the resources appear sufficient.

Reviewer 3:
The reviewer stated that the resources appear to be sufficient for achieving the objectives of this work.

Reviewer 4:
The reviewer commented that the resources listed appear sufficient.

Presentation Number: eems034
Presentation Title: Optimization of Intra-City Freight Movement and New Delivery Methods
Principal Investigator: Amy Moore (Oak Ridge National Laboratory)

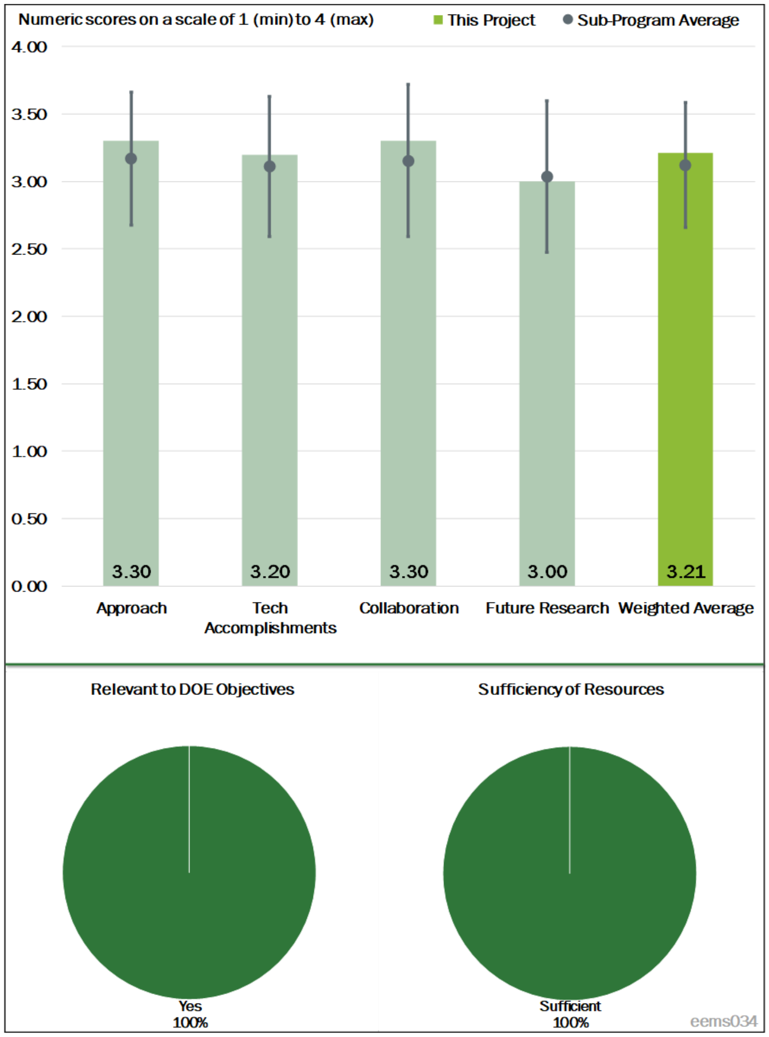

Figure 3-20 - Presentation Number: eems034 Presentation Title: Optimization of Intra-City Freight Movement and New Delivery Methods Principal Investigator: Amy Moore (Oak Ridge National Laboratory)

Presenter
Amy Moore, Oak Ridge National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer commented that the approach for developing estimates of how new freight modes and technologies might affect freight energy efficiency is sound. The project team has engaged several good partners to collect data on freight patterns (most specifically United Parcel Service [UPS]). The reviewer stated that the team is pursuing a useful data-driven dual-model approach (tour-based and freight delivery) that can explore the effects of different parameters on freight movement. The team has incorporated several technologies that are in the forefront of freight efficiency discussions (drones, electric vehicles, Uber-style passenger freight) and this work should be valuable to help ground the discussions around what benefits these technologies will have.

Reviewer 2:
The reviewer noted that the collaboration with UPS to obtain real trip information then build freight delivery demand model is a very good first step of this research. Parcel weight analysis shows the potential of drone delivery. The reviewer commented that the energy consumption experiment seems a little too simplified.

Reviewer 3:
The reviewer noted that the project, being a first for DOE in this topic area, is by nature a bit less concrete in its scope and objectives. It is impressive that the project team has made such progress on the models, scenario planning, and future plans.

Reviewer 4:
The reviewer pointed out that the research plan is sound. The team has focused early efforts on data collection and analysis and assessment of energy reduction for new freight modes. The reviewer commented that the

project activities build towards development of comprehensive tools that can assess the application of new freight modes and technologies on city and regional bases. The research covered new freight modes and technologies including drones, parcel lockers, EVs, and uber-like delivery systems. The reviewer stated that evaluation of additional modes and technologies might also be of interest as budget allows. Further, the delivery scenarios applied in the FY 2018 work were developed in-house; the project team indicated that additional input will be solicited from project partner UPS and other commercial delivery companies for broader coverage of interest to the industry.

Reviewer 5:

The reviewer remarked that technical barriers are also created by the environment and system they must work within. There are a few requirements that need to be checked for a full understanding of the energy impact. One of these is security and the second is the allowable flight path of a drone.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer mentioned that the project team used just one month of UPS data to analyze freight movement in the Columbus metro area—this might be a concern depending on which month was picked (assume UPS picked a representative average month for this project). As package delivery can be cyclical (particularly around the holiday season) an additional month or two to bracket UPS deliveries would be helpful (understanding that second-by-second data for GPS+CAN is a lot of information to process). The project team is discussing this as a remaining challenge and this reviewer would recommend obtaining those additional data. Overall, the reviewer concluded that the team has accomplished a good amount and the results appear to be useful. The team is clearly working diligently to present results to the research community through papers and technical talks, which is very valuable.

Reviewer 2:

The reviewer commented that the project has a good plan, followed up by an excellent analysis.

Reviewer 3:

The reviewer stated that the trip demand should closely depend on income/earning level. It is also known that university students have disproportionally high delivery. If the developed model is to be scalable to other cities, more data need to be obtained in order to build a more robust model. In terms of energy consumption model, the reviewer asked if the project team has considered using "flight time" instead of miles as a key parameter.

Reviewer 4:

The reviewer commented that the duty cycle understanding with UPS was very good, that the project has strong scenarios for consideration, and that the analysis is well done.

Reviewer 5:

The reviewer stated that the project team indicated that the work is about 50% complete as of the AMR conference. This seems appropriate for a 3-year project that started in October 2016. The reviewer said that FY 2018 progress includes the collection and analysis of UPS, CAN, and GPS data for Columbus, development of delivery demand estimation model for Franklin County, and development of delivery scenarios using new freight modes and technologies compared with the current baseline. For this latter effort, the reviewer remarked that some valuable insights have been gained regarding EV and delivery locker benefits. To date, the research has generated 11 presentations and one paper.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer noted that collaboration on the project has been excellent. The research team is working with SMART Mobility Consortium members, NREL (data collection and analysis) and INL (drone characterization and energy use), as well as industry partner UPS (CAN and GPS data for Columbus) and MORPC (socioeconomic and business data for Franklin County). The project team indicated that there will be additional coordination with UPS on Columbus data and input to viable freight modes as well as other parcel delivery companies.

Reviewer 2:
The reviewer noted that the team is collaborating with UPS, which can provide a very good perspective on freight movement. The MORPC Smart City connection is also valuable. Overall, the reviewer concluded that this is a good collaboration between ORNL, NREL, and INL with tasks for each national laboratory logically established.

Reviewer 3:
The reviewer noted that there is a good combination of partners involved to represent this work.

Reviewer 4:
The reviewer commented that there is good collaboration with UPS in obtaining data; however, the team could better explain the collaboration approach among researchers.

Reviewer 5:
The reviewer remarked that the collaboration with UPS is great, but that there is not much collaboration evident with too many others. The reviewer suggested that more partners be included in future work on the last mile.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that working on increasing sample size is good as this will add more depth to the analysis. The drone analysis will be useful as this is a topic that garners a lot of attention in the press, so understanding how these would be used in last mile delivery would make the discussions more rational and fact-based. The reviewer stated that the review of the traffic congestion versus freight issue is also important—freight companies are very in tune with how congestion costs them money (in lost productivity and fuel) and consumers have more and more interest in getting next-day or same-day delivery, both issues that traffic congestion will affect. The per-parcel energy use will be an interesting metric. The reviewer presumes this will be based on the average package size listed in the presentation so it would be good to also express this per cubic foot and per pound as both metrics are of interest to freight companies.

Reviewer 2:
The reviewer said that future potential research should be planned out in more detail and perhaps a deeper discussion with partners and other stakeholders on the government side, i.e., drone regulation per the Federal Aviation Administration (FAA), zoning issues for lockers, etc.

Reviewer 3:
The reviewer remarked that the proposed future work is well laid-out and builds off of earlier activities for achieving overall project objectives. The project team has proposed gathering additional UPS seasonal data for more robust coverage of annual freight demand and movement, developing additional freight movement

scenarios for broader coverage of modes and technologies, creating a MEP metric, performing a closer review of drone use for last mile delivery, refining energy use parameters, and developing a TransCAD-based program using mileage and scenario type inputs.

Reviewer 4:
The reviewer suggested that more partners be included on future work on last mile.

Reviewer 5:
The reviewer commented that the future work described for FY 2018 and FY 2019 is at a very high-level and vague.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer remarked that this project is relevant to DOE goals as energy efficiency opportunities for freight movement are important to VTO. The connection to the Smart City activity in Columbus is also relevant.

Reviewer 2:
The reviewer commented that yes, this project reflects an interesting array of choices for last mile delivery.

Reviewer 3:
The reviewer remarked that last mile is not only a hot topic, but many firms are moving very fast satisfying demands of impatient consumers. The reviewer asked if we are creating another unsustainable form of goods movement. The reviewer was not sure, but it is good to see projects like this one helping to figure it out. Both the extent of the opportunities and the adverse consequences that might come from them.

Reviewer 4:
The reviewer said that this project supports the overall DOE EEMS program objectives in conducting research on energy consumption impacts of novel multi-model freight movement and associated analytical tool development.

Reviewer 5:
The reviewer noted that studying alternative freight delivery mode using drones is a worthwhile extension of the current VTO research portfolio. The energy characterization approach, however, is very simplistic. The reviewer stated that it should take advantage of model science/physics based approach, instead of just be satisfied with curve-fitting test results from a single drone.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that the resources appear to be sufficient to complete the project as described.

Reviewer 2:
The reviewer commented that the resources for FY 2018 are sufficient for the proposed work.

Reviewer 3:
The reviewer stated that the resources are sufficient.

Reviewer 4:
The reviewer said that the project appears sufficiently funded for the activities proposed.

Presentation Number: eems035
Presentation Title: Coupling Land-Use Models and Network-Flow Models
Principal Investigator: Paul Waddell (University of California-Berkeley)

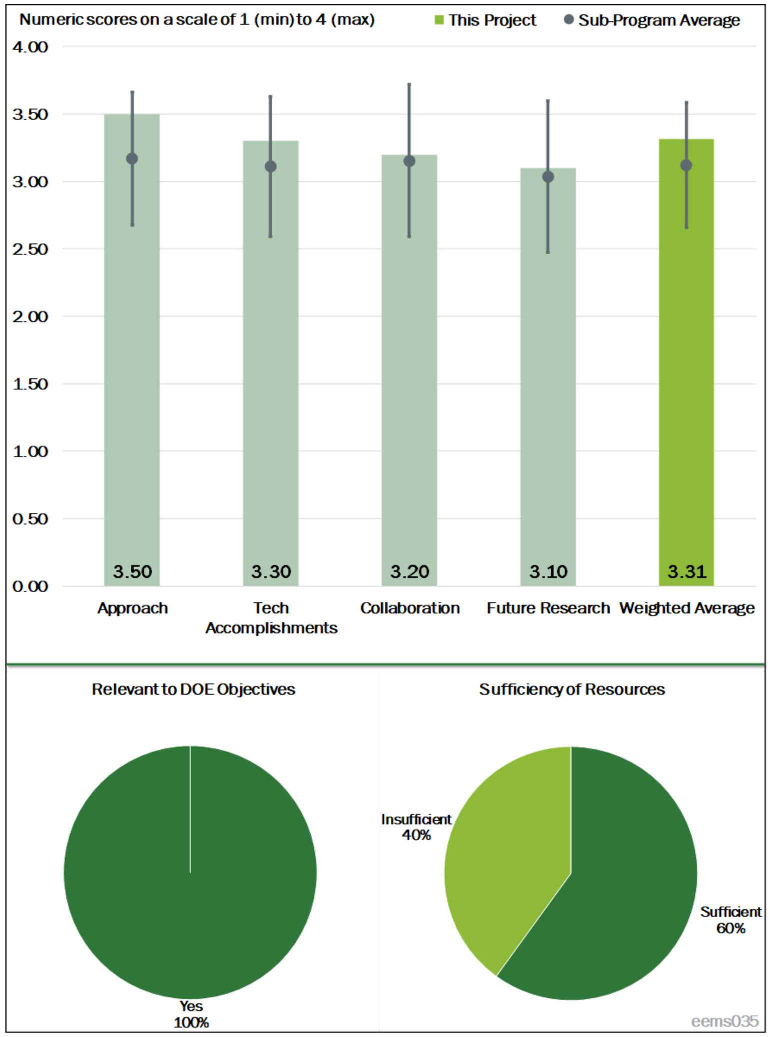

Figure 3-21 - Presentation Number: eems035 Presentation Title: Coupling Land-Use Models and Network-Flow Models Principal Investigator: Paul Waddell (University of California-Berkeley)

Presenter
Paul Waddell, University of California-Berkeley

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer stated that the python-based pipeline seems like a feasible and effective method.

Reviewer 2:
The reviewer remarked that this project is very challenging when linking so many different modeling platforms, but it is feasible.

Reviewer 3:
The reviewer commented that the objectives are well laid-out with respect to the barriers; however, the connection to energy consumption could be made clearer and more explicit.

Reviewer 4:
The reviewer noted that this project seems to provide a comprehensive solution to understanding how land use planning factors in to transportation decision-making (and the impact it can have on saving energy) as well as how land use must adapt to changing travel models. This question could make or break whether a city can successfully implement sustainable transportation systems.

Reviewer 5:
The reviewer commented that this presentation does a good job of explaining what this project is trying to achieve and why the work is worth doing. Based on the presentation, the work is reasonably well-conceived and definitely well-organized. The reviewer remarked that the PI seems to understand what the team wants to accomplish and what tools and improvements are required to achieve those goals. The PI identified what the other team members are doing and he showed how the work comes together to address the objectives. The PI identified some of the deficiencies in the current tools and how they will be overcome. The reviewer said that the presentation uses a few of the general and ill-defined phrases that seem to be common in these urban mobility modeling efforts, such as “alternative traffic assignment models” but it keeps these to a minimum and

provides a clearer picture of the tasks than most other presentations the reviewer has seen. However, the reviewer thinks it would still be further improved if the PI and the team could provide more details or more examples that help illustrate the issues and approach. Slides like 16, 17, and 18 give reviewers a better idea of how the problems are formulated and then addressed. Slide 13 gives one a feel for the computational intensity involved. The reviewer concluded that more information at this level of detail and beyond would raise this score further.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that progress has been reasonable for the relatively short period of time the project has been active. Getting the architecture of the overall model set and then incorporating the network flow and UrbanSim models seems like an acceptable level of accomplishment. Because the work plan is clearly defined and the work so far has followed the plan, the reviewer has considerable confidence that such progress will continue.

Reviewer 2:

The reviewer commented that the emphasis on speed of processing to rates that match the UrbanSim platform processing is unclear, when 30 year “runs” encompass extremely large periods of time for travel demand when year-by-year data exchange between modes is required. The reviewer stated that the essential aspects of this approach to create integrated models are excellent, but the authors did not really explain the stipulation of processing speed. The reviewer asked if processing 30 years of data takes 8 hours versus 1 hour, is that a fatal flaw to reaching the project goals. The reviewer suggested that going forward, this should be defined in terms of the objective for processing time for a given scale of regional models.

Reviewer 3:

The reviewer stated that the project appears to be on task per the presented schedule.

Reviewer 4:

The reviewer commented that it appears that everything is on track to be complete by the final project deadline.

Reviewer 5:

Regarding full network, this reviewer reported a quarter million nodes, half a million edges, and 53,000 km of streets across 9 counties, which is good progress if this has been accomplished. If not, the reviewer commented that the presentation is misleading.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that there is a wide variety of partners and stakeholders.

Reviewer 2:

The reviewer noted that the project has a large group of collaborators and all seem to have important roles.

Reviewer 3:

The reviewer stated that there seems to be a good amount of varied collaborators. It is not clear from the presentation the extent of their participation and involvement. The reviewer asked if there are any collaborations with other federal entities.

Reviewer 4:

The reviewer said that collaboration appears to be good because the PI has defined what each participant will be contributing and identified the form of some of the data or models that will be transferred. This score would be even higher if more specific examples of data transfer could be provided, but it is early in the project and the reviewer expects that will happen over time if each team member fulfills its role. The reviewer pointed out that Slide 8 provides some indication of the roles, but more details would justify a higher score

Reviewer 5:

The reviewer was not able to determine an answer to this question from the presentation or the slides.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that performance and runtime improvements, testing on multiple street networks, testing multiple traffic assignment suites, and code repository to run at scale are all appropriate future research, but quantitative metrics for these would be helpful in evaluating the effectiveness of the project.

Reviewer 2:

The reviewer noted that the proposed future research aspect could be strengthened by discussing how the partners will be used and where they fit in. The reviewer asked if there is a plan for beta testing with potential end-users (planning agencies, etc.) or getting their input as the model is refined.

Reviewer 3:

The reviewer stated that future work involves a number of improvements to the model, replicating for other urban areas, and providing technical documentation, all of which seem like natural extensions of the current research.

Reviewer 4:

The reviewer noted that it is not clear what has already been accomplished or whether the presentation is showing the capabilities of existing platforms that are intended to be linked through the Python pipeline. The reviewer stated that the plan has several options for the traffic assignment component, but the leveraging of the large datasets (other than traffic assignment) is unclear. For example, the rich dataset of multimodal trip components offered in behavior energy autonomy mobility (BEAM) do not seem to be included in the planned "pipeline" approach. The reviewer asked if this a feature that can be added (if not already addressed). The reviewer commented that the benefit of applying BEAM is that even if traffic is all that is used when traffic assignment is the purpose of it application, the empty-vehicle movements of ride-hailing services (and possible private vehicle "send home" trips) will be included in the data pushed through the pipeline.

Reviewer 5:

The reviewer stated that after the project team presented a reasonable overall plan and identified some reasonable accomplishments, the information provided about future work is somewhat disappointing. Future tasks are presented as seemingly independent activities and did not address their interrelationships. The reviewer remarked that it does not appear that the project team created a logical path to overcoming any specific barrier or achieving any specific goal. Milestones were not identified. The reviewer commented that generalities such as "performance improvements" and "scaling up" do not provide anyone with a sense of exactly what will be done, how or why it is challenging, or where it will lead. The project team needs to plan its future work more carefully and describe it more fully.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted that the connection to a VTO/EEMS strategic goal is clearly stated and evident.

Reviewer 2:
The reviewer stated that the project description specifies that it "supports VTO/EEMS strategic goal to develop new tools, techniques, and core capabilities to understand and identify the most important levers to improve the energy productivity of future integrated mobility systems."

Reviewer 3:
The reviewer remarked that this project supports DOE's objectives by exploring the relationship between urban development and mobility, and it does so by using some known models (UrbanSim, ActivitySim), integrating them, and then addressing their deficiencies in either processing speed or validation against data. Because of this approach and the modular nature of the model architecture, it appears to the reviewer that this project promises to have more impact and to produce more useful insights than the other projects they have seen.

Reviewer 4:
The reviewer said that the obvious benefit of HPC for such a large amount of computing is understood to be an objective of DOE. The question will be whether non-HPC applications will be possible by a typical metropolitan planning organization (MPO). The reviewer concluded that even so, the objectives of DOE seem to be fulfilled.

Reviewer 5:
The reviewer said that the project evaluates the combined policy impacts of land use and transportation at regional scale over several decades. If this is accomplished, then it will be relevant to DOE objectives. The reviewer concluded that it is difficult to say from the presentation or the slides if this will be accomplished.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that, once again, this is a very difficult question to answer based on the way it is posed and the sparse nature of the budget information provided. The reviewer graded these resources as "insufficient" because the funds going to this work seem fairly low compared to some of the other projects reviewed. Because of the clarity of vision that this project team seem to have, it appears that additional resources might be productively applied, more so than some others.

Reviewer 2:
The reviewer remarked that the objectives for creating such a comprehensive pipeline would appear to be insufficient in dollars and possibly time. The reviewer concluded that incorporating DOE resources such as HPC would appear to need additional funding to be accomplished.

Reviewer 3:
The reviewer said that the resources for this project seem to be in line with the level of effort and expertise required.

Reviewer 4:
The reviewer said that the presentation did not mention any issues with the resources they have.

Reviewer 5:
The reviewer commented that the funding amount seems appropriate for the size and reach of the project.

Presentation Number: eems036
Presentation Title: Reinforcement Learning-Based Traffic Control to Optimize Energy Usage and Throughput
Principal Investigator: Tom Karnowski (Oak Ridge National Laboratory)

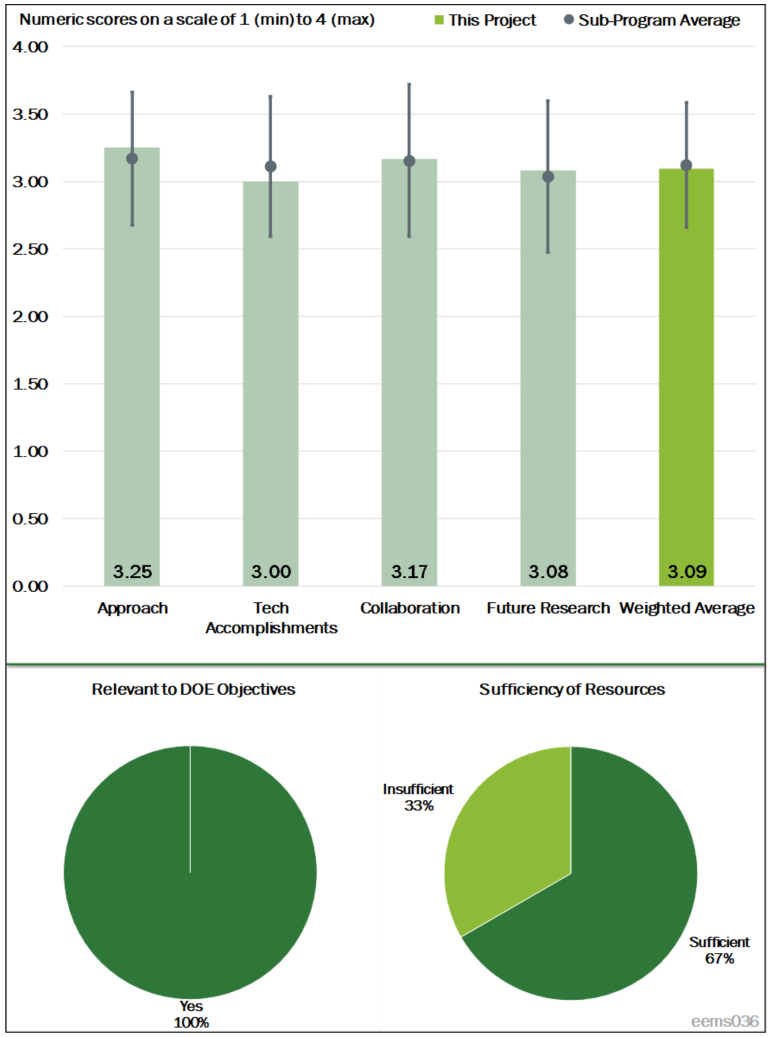

Figure 3-22 - Presentation Number: eems036 Presentation Title: Reinforcement Learning-Based Traffic Control to Optimize Energy Usage and Throughput Principal Investigator: Tom Karnowski (Oak Ridge National Laboratory)

Presenter

Tom Karnowski, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the project has a very practical approach.

Reviewer 2:

The reviewer observed that the project utilizes existing technologies and analytic tools to vehicle classify and estimate fuel consumption, with the aim of optimizing both fuel consumption and vehicle throughput. The project team's methodology seemed clear, relevant, and generally viable, and the team has already acquired datasets for training, vehicle classification, and from a naturalistic driving study. The reviewer would be interested to learn more about their real-world implementation strategies.

Reviewer 3:

The reviewer commented that using video images and vehicle classification are viable and useful concepts for transportation data collection.

Reviewer 4:

The reviewer noted that the project approach is technically sound and well-designed. It is therefore possible that the goals and objectives of the project may be realized. The technical approach, based on the use of machine learning (ML) to estimate and predict fuel consumption using GridSMART cameras, is based on recent successes in ML and the significant computational resources that HPC can bring to solving the challenge. The reviewer commented that using cameras with a wide field of view (fish eye lenses), allows for the capture of sufficient information regarding the vehicles that pass by at the relevant locations. These can replace the inductive loop systems that are in place today. The reviewer stated that utilizing ground systems to capture the images that then can train the ML algorithm, specifically with reinforcement learning, is appropriate. The project is based on the relatively mature field of computer vision technology and trends in reinforcement learning. Recent breakthroughs in "deep learning" have challenged computer vision approaches; however, there are continuing challenges in ML with achieving sufficient accuracy of image recognition and the inability to explain the success or otherwise of actions taken through ML experience. The reviewer concluded that the project results can shed light on some of these challenges.

Reviewer 5:

The reviewer conveyed needing much more detail to understand the approach.

Reviewer 6:

The reviewer commented that the ability of GridSMART to deliver an operable system may be a risk. The project is feasible, but the methodology of automated classification should be designed to be transferable to other detection systems to be truly useful. The reviewer remarked that the changes in fuel consumption by vehicle class may require future updating of traffic control algorithms that are more site and operating environment specific. Recognizing that in a 10-minute presentation not many details can be provided, it is unclear how wholly different vehicle classification mixes (unique to each location) are accommodated in the algorithms to be derived, or whether sufficient variations in the case studies will be accomplished in the associated HPC ML runs to provide a complete library of algorithms for any situation. The reviewer noted that further, it is unclear how different control algorithms will be utilized by local traffic management entities or controller manufacturers, or if the family of algorithms would reside in the controller and be dynamically applied as traffic mix changes.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that the project is right on track.

Reviewer 2:

The reviewer stated that with the project only being several months in, the progress appears to be on track.

Reviewer 3:

The reviewer remarked that this project is only 10% complete, although this level of accomplishment and progress appears to have been due to non-technical issues. However, the project has identified the necessary cameras for data collection, acquired datasets for training from ground cameras, the necessary tools for classification of images, and ample vehicle traversals through intersections. Further, the reviewer concluded that HPC designs have been formulated for grid characteristics.

Reviewer 4:

The reviewer said that the project still seems very much in the exploratory phase, but the reviewer is not able to tell based on the current description of the approach.

Reviewer 5:

The reviewer remarked that the project team noted that the project was not reviewed last year and that only a month of work (the initial beta collection and analysis) has gone in to it so far. Having said that, this progress seems consistent with the timeline provided in the team's slides. Specifically, until now their action items have included working on acquiring GridSMART vehicle data, building a training set, and designing/developing HPC software. The reviewer concluded that based on the datasets the team has acquired and the work the team reported having already done towards preparing for the next steps of the project, it seems the team is basically on schedule.

Reviewer 6:

The reviewer noted that the level of completion is not in line with the project age and duration.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that this project has a good team assembled. The reviewer commented that the project team should consider a commercial partner.

Reviewer 2:

The reviewer stated that the materials and presentation mentioned partners (existing and potential). Because it is still early in the project, the existing coordination seems sufficient. The reviewer would later be interested to know with which municipalities the project team collaborates and the outcomes of those partnerships.

Reviewer 3:

The reviewer commented that the project is based on the collaborative work with GridSMART and that their provision of camera characteristics and operating parameters is very important. Involving local municipalities will help provide a practical view of the utility of the study results. The reviewer concluded that all of these parties would seem to be highly motivated to support the research project work.

Reviewer 4:

The reviewer stated that the team has identified the necessary collaborator for the success of their project. GridSMART is located in Knoxville, Tennessee. Geographic proximity to the team partner will help with collaboration and coordination of various aspects of the project such as data collection, discussion of technical issues, and effectively utilizing the HPC resources that are available at ORNL. The reviewer commented that additionally, because the team consists of only the company GridSMART and ORNL, the challenges in collaboration and coordination on the project are simplified. The data collected by the GridSMART cameras and the ground cameras represent the key data sources for the project. The reviewer noted that ORNL accomplishes the data processing through computer vision and reinforcement learning based on the HPC resources that exist at the national laboratory. The simplified team structure should help accelerate the project. Other potential partners—municipalities—are mentioned such as Allentown, Pennsylvania, Sevierville, Tennessee, and Chattanooga, Tennessee. The reviewer concluded that these partners can broaden the opportunity for the project.

Reviewer 5:

The reviewer was unable to determine the level of collaboration from the slides or presentation.

Reviewer 6:

The reviewer could not tell the role of each stakeholder from the current description.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted that the project has good plans moving forward.

Reviewer 2:

The reviewer stated that the project provided details pertaining to future work focusing on both data and HPC. Given that training data are sufficiently granular and varied, the process the team has laid out for classifying vehicles and estimating energy consumption seems promising. With respect to HPC software, the reviewer is curious to learn more about the parameters that will be applied to simulations. Additionally, the reviewer would be interested to learn more about the real-world deployment strategy of this project and how this system will be implemented. The reviewer asked how the system will prioritize and re-route vehicles once it has been adequately trained to classify and characterize them effectively. The reviewer also asked if, in order to reduce net emissions/idling time, certain vehicles (and therefore vehicle owners) will be at a disadvantage with respect to routing, etc.

Reviewer 3:

The reviewer noted that the proposed future work and deployment are necessary for the project to be successful.

Reviewer 4:

The reviewer said that the future modeling work on large scale, and the ability of the Reinforcement Learning processing in the HPC application, is of key importance, since, even if the GridSMART technology application proves deficient, the algorithms will be applicable to other means of defining site specific vehicle classification mix.

Reviewer 5:

The reviewer commented that the description needs more detail about specifics. The reviewer asked how the team will approach each of these things.

Reviewer 6:

The reviewer stated that the project proposal for future research is organized into two themes: Data focus and HPC focus. These are complementary to each other. The reviewer said that the planned work is logical in that the training data is critical for the performance of the ML approach and this is shown as one of the early tasks. The team logically placed the proposed milestones in sequence. The reviewer pointed out that decision points are shown as milestones; however, go/no-go metrics are not shown as the project assumes that the proposed approach with computer vision technology and reinforcement learning will be successful (which remains to be seen). Alternate algorithms and approaches are not proposed to mitigate the risks with relying on the proposed methodology.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer commented that this project will help save fuel and reduce congestion.

Reviewer 2:

The reviewer stated that the project includes using connected and automated technology to improve efficiency in the transportation system.

Reviewer 3:

The reviewer pointed out that part of DOE's mission is to address energy and environmental challenges. This project aims to create a technology solution that could help to improve energy productivity/efficiency. The reviewer concluded that it is therefore directly relevant to (and working in support of) the objectives of the DOE.

Reviewer 4:

The reviewer said that the provision of traffic control algorithms that can maximize fuel consumption dynamically as a function of traffic vehicle classification mix is very valuable.

Reviewer 5:

The reviewer commented that this project has sufficient relevance for meeting the overall goals for DOE's VTO. The end goal of saving nearly 6 billion gallons of fuel annually (idling costs) is directly relevant to the goal of energy-efficient mobility. The reviewer said that the innovative approach that the project team has chosen with GridSMART cameras and ML/HPC, leverages significant computational resources that exist at ORNL. Additionally, the use of wide field of view cameras that can potentially replace legacy sensors to provide additional capability in mobility sensing and route planning in the future has significant potential for the future of vehicle transportation networks. The reviewer concluded that new infrastructure that may be created through this project can be scaled to provide improved energy-efficient mobility throughout the United States and to other countries to increase economic benefits for our nation.

Reviewer 6:

The reviewer stated that methods of collecting high resolution detailed traffic data are needed.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that if 2018 funding is not secured, $50,000 seems unlikely to be sufficient to complete this work.

Reviewer 2:

The reviewer remarked that completing the HPC processing to accomplish the ML step on sufficiently large networks could be a challenge that requires additional resources. If the other technology aspects are suitably resolved to justify additional HPC modeling implementation resources for this step, the reviewer recommended providing additional resources.

Reviewer 3:

The reviewer said that thus far, the resources seem sufficient. The reviewer thanked the project for presenting and looks forward to learning more about the work and its outcomes.

Reviewer 4:

The reviewer commented that the funding level is consistent with the level of effort and expertise required for this type of work.

Reviewer 5:

The reviewer commented that the project should consider a commercial partner.

Reviewer 6:

The reviewer stated that the resources for the 1-year project with just two teams (GridSMART and ORNL) considering the computational resources that already exist at the national laboratory, seem sufficient. The project aims to demonstrate feasibility of the proposed concept. The reviewer said that as the project has not stated quantitative metrics for accuracy, precision and other technical parameters, a 1-year effort appears to suffice for concept viability. However, the reviewer pointed out that scalability, techno-economic analysis, business case, and other related challenges in commercializing the technology will need to be addressed through future funding beyond the current project.

Presentation Number: eems037
Presentation Title: High-Performance Computing (HPC) and Big Data Solutions for Mobility Design and Planning
Principal Investigator: Jane Macfarlane (Lawrence Berkeley National Laboratory)

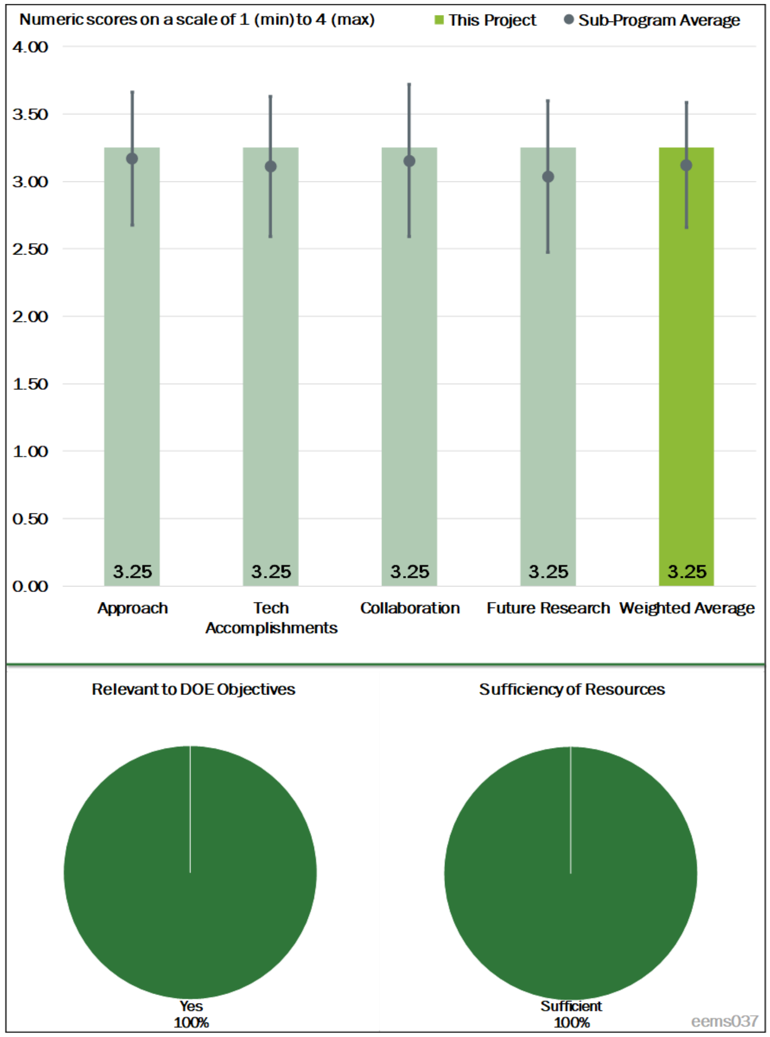

Figure 3-23 - Presentation Number: eems037 Presentation Title: High-Performance Computing (HPC) and Big Data Solutions for Mobility Design and Planning Principal Investigator: Jane Macfarlane (Lawrence Berkeley National Laboratory)

Presenter

Jane Macfarlane, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that this was a very well laid out project as well as presentation. What was well done were the relevance (Slide 3), work breakdown (Slide 4), milestone (Slide 5), and approach. The reviewer stated that the flowcharts were also very easy to understand.

Reviewer 2:

The reviewer stated that the modelling approach is global but exploits parallelism. The reviewer commented that the approach is robust.

Reviewer 3:

The reviewer remarked that the project is addressing a tremendous challenge in urban scale vehicle networks with the added complexity of ingesting and analyzing real-world data in near real-time. The technical approach is based on utilizing HPC resources that are available at the national laboratories. Specifically, the reviewer stated that the challenge is to develop the right set of tools for rapid modeling of large scale transportation networks to assess energy productivity and efficiency of vehicle mobility. The energy cost and productivity loss of congestion are expected as outputs of the analysis. The reviewer commented that a multi-lab effort to develop the Data Science, and the HPC computational framework for next-generation mobility system models and operational analytics is envisioned. The project is well-formulated with a systematic approach to include gap analysis, definition of system architectures, data access and analytics, and identification of ML tools for HPC. Long short-term memory (LSTM), a thoroughly researched ML approach, is chosen for analysis of geospatial temporal data. The reviewer said that the project team has given sufficient attention to all aspects of the project challenge. The team is also realistic about the potential of the success of the project having stated all the critical assumptions. The reviewer said the impact of assumptions such as the use of flat maps for energy consumption for now, and constant speed through each link, are not yet clear and remain to be ascertained.

The reviewer noted that an HPC-based Machine Learning approach to address the proposed challenge is feasible. The question remains as to what the quantitative performance of the proposed solution will be and if it provides insights that may be implemented in alleviating the congestion experienced in real-world situations. The reviewer stated that a related issue is with translating the lessons learned from HPC-based methodologies for Data Center and distributed computing architectures that are relevant to real-world scenarios. With increasing computational resources on vehicles and at the edge of the network, implementing ML approaches on distributed systems will become the norm in the future. The reviewer concluded that a potential solution to this conundrum may be to support a parallel research effort on data-centric systems to compare and contrast the pros and cons of these two methodologies: HPC based and data center-based.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that the goals presented were not clear. The reviewer asked what the ultimate tangible outcome of this work is.

Reviewer 2:
The reviewer commented that it was helpful to see the simulation results, albeit it is just the beginning (Slide 12). The reviewer suggested that if the project team could really get to a simulation of the types of vehicles on the road, along with analysis of fuel consumption during congestion, or without congestion, it could help optimize design/engineering of the vehicles.

Reviewer 3:
The reviewer commented that the results are solid and the schedule appears to be on track.

Reviewer 4:
The reviewer said that the project appears to be on track as seen from the milestones that have been accomplished since project inception. Specifically, PNNL has completed deployment of initial HPC and HPC-ML toolset having selected the initial HPC-ML tools. LBNL is providing project coordination, defining the appropriate role of HPC, ML, and Big Data analytics for transportation, and is also on track to establish organizationally efficient data access processes. LBNL also has the lead on developing asynchronous distributed state HPC transportation network models and have a go/no-go planned for Q4 (FY 2018) on this task. The reviewer stated that ANL has completed selection of initial training dataset from the Connected Corridor, and are on track for demonstrating the viability of the LSTM neural architecture approach for G-T data. ORNL has defined the path for integration of energy models into the HPC framework and have established a go/no-go in Q2 of FY 2019 to evaluate the efficacy of the ML approach and impact of data veracity on energy estimates. The reviewer noted that quantitative estimates are shown for the loss of productivity across links; up to $2,000 loss per 15 minutes on the top congested links for a total daily loss of more than $6 million. Such quantitative measures are significant accomplishments for the overall project and highlight the need for energy efficient mobility solutions.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer stated that the project has good collaboration with Uber travel analysis zone (TAZ) movement data and that there are other good collaborations as well.

Reviewer 2:

The reviewer liked seeing the collaborations and coordination as outlined in the project. The reviewer does think that there are other opportunities to bring available data into this project, which the team may not have thought of.

Reviewer 3:

The reviewer commented that the project team consists of the four DOE national laboratories, LBNL, PNNL, ANL, and ORNL, in collaboration with the Connected Corridor program, University of California-Berkeley, and Cal Trans. Based on the progress made on the project and the interrelated nature of the sub-projects across the various national laboratories, there seems to be excellent collaboration and coordination on the project. The reviewer remarked that each national laboratory has a unique role and contribution that complements their partners, and this approach ensures that there is value-add from each partner on the team. Additionally, the team also has “here” for GPS data for the Connected Corridor Region and Uber for TAZ Movement Data/Validation.

Reviewer 4:

The reviewer said that there were no details presented on collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted that the proposed research seems feasible and high impact in light of the progress.

Reviewer 2:

The reviewer stated that the proposed future research is logically aligned with the ongoing project and accomplishments. The proposed efforts such as automated, data-fusion ML models, dynamic routing, impact of routing on energy, productivity and mobility measures, datasets for large-scale network characterizations, and real-time decision making are important future goals for the project. The reviewer commented that alternate technical development pathways, although not explicitly stated, may be realized through a choice of ML models and other changes/modifications as needed.

Reviewer 3:

The reviewer explained giving the project a satisfactory in hope that it is actually on a good track. The reviewer remarked that the proposed future research was unclear.

Reviewer 4:

The reviewer commented that the project team is just scratching the surface but that the team also has to think of “what the end game” is for analysis. The reviewer asked how much energy can be saved and at what cost for simulation.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer stated that the problem being solved is critical to the type of simulations needed for transportation planning. Reducing computation time is critical if these and other models are going to be useful.

Reviewer 2:

The reviewer remarked that this DOE project based on HPC and ML for EEMS is highly relevant to DOE/VTO’s mission. HPC offers unique capabilities as a platform for ML tools that may provide new insights into urban vehicle networks and transportation to address some of the inefficiencies in the system that cannot be easily solved with traditional analyses and calculations on commonly available tools. The reviewer concluded that a successful outcome for the project can potentially lead to billions of dollars saved annually for the U.S.

Reviewer 3:

The reviewer said that yes, this does support DOE objectives. The reviewer commented that it would be helpful to have an end game in mind for energy savings, which the project team would then show in their simulation. The reviewer asked what the end game looks like.

Reviewer 4:

The reviewer hoped that this project supports DOE's overall objectives, but it is not clear if it does.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that the resources are typical for this type of effort.

Reviewer 2:

The reviewer stated that the project resources seem to be sufficient considering the resources that the team is utilizing and the tasks/milestones envisioned for the project. At an average cost of $500,000 per DOE national laboratory, the project resources seem realistic and reasonable. The reviewer commented that the project outcomes in the first year can provide additional justification and evidence for the level of resources that are required in subsequent years of the project. A detailed cost plan showing the types of resources required for specific tasks will add further support to sufficiency of resources requested.

Reviewer 3:

The reviewer hoped the project has enough resources to result in a good result; however, it is unclear form the presentation that it does.

Reviewer 4:

The reviewer stated that the project has a rather large budget, $2 million per year—for $6 million in total across 3 years. The reviewer asked if the project team is getting what they need from each of their partners, including the Connected Corridor, University of California-Berkeley, and CalTrans. The reviewer asked what more does the team need to be efficient and what does the team not need. The reviewer reiterated that the project team should determine the end game from an energy savings standpoint.

Presentation Number: eems038
Presentation Title: Fuel Selection of Privately Owned Shared Vehicles
Principal Investigator: Shawn Salisbury (Idaho National Laboratory)

Presenter

John Smart, Idaho National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

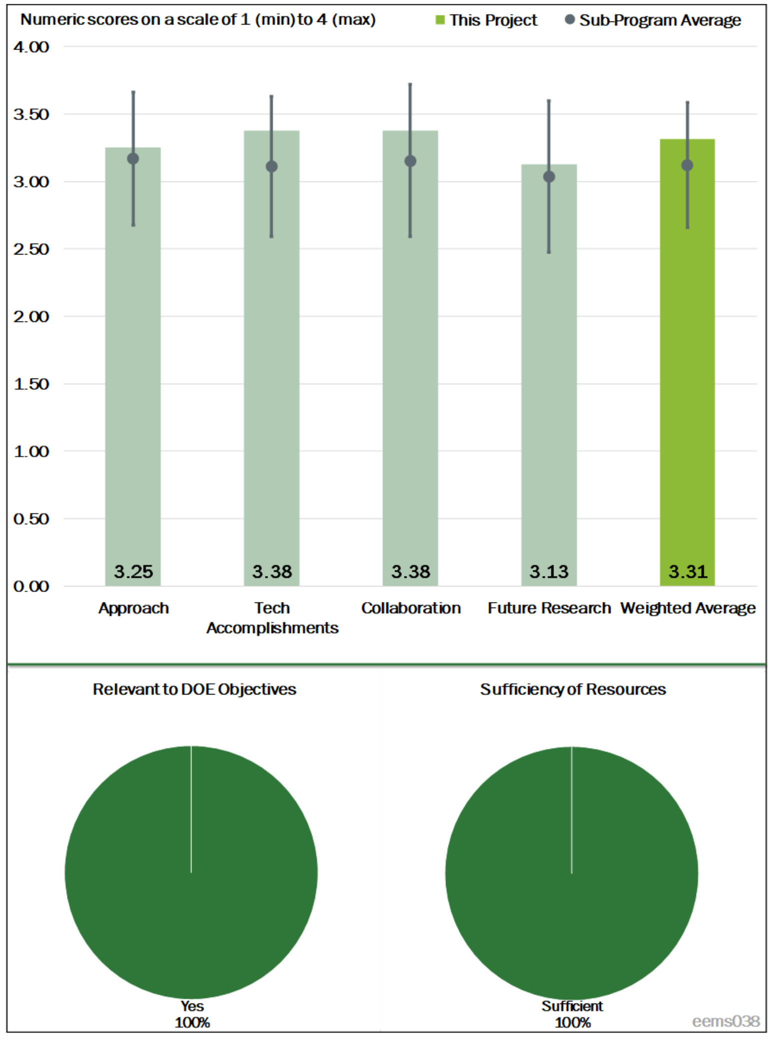

Figure 3-24 - Presentation Number: eems038 Presentation Title: Fuel Selection of Privately Owned Shared Vehicles Principal Investigator: Shawn Salisbury (Idaho National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer really liked this project and approach. In particular, the report-out also was “real world based” and easy to understand.

Reviewer 2:

The reviewer remarked the approach is appropriate, and the team has done an excellent job given the limited data availability.

Reviewer 3:

The reviewer remarked that the overall project approach seems focused on addressing specific issues. One particularly advantageous element of the approach is incorporating real-world data (from multiple sources) to inform the analysis methods. The reviewer pointed out this allowed the project to estimate potential cost structures for recharging, and it also assisted greatly in determining priorities for locating recharging equipment (such as utilization rate being more important than cost).

Reviewer 4:

The reviewer commented the relevance of the project relies on the assumption that the adoption of shared vehicles with EVs could be substantial enough to overwhelm the existing/planned infrastructure for non-shared vehicles. While the presenter noted data availability is an issue, baseline assumptions using incumbent taxi fleets should provide a good estimate of shared vehicle contributions to overall VMT. The reviewer pointed out that projected shared vehicle growth rates and EV adoption rates (both shared and non-shared) would provide suitable reference points to predict the potential impact. The formal presentation of the anecdotal examples showing localized deficiencies in charging infrastructure would further demonstrate the relevancy of the project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the project is on track and has already provided some interesting insights into charging infrastructure deployment.

Reviewer 2:

The reviewer commented that so far, the project team is at quarter two of FY 2018 with simulations being complete. The reviewer looks forward to seeing the results from quarter three and quarter four for FY 2018, which starts to look at economics.

Reviewer 3:

The reviewer noted that the team has evaluated a great deal of real-world data, and determined several key results. These results then pointed to several very important infrastructure development considerations, which helped to determine specific infrastructure scenario plans. The reviewer cited as an example how the project verified home charging as a critical infrastructure source. While the team may have anticipated this, the project generated sufficient results to document exactly how critical.

Reviewer 4:

The reviewer said that for shared mobility applications, it would be valuable to determine the impact of satisfactory and unsatisfactory levels of infrastructure on EV usage for privately owned ridesharing vehicles. In addition, the change in behavior of ride operators/owners to availability of charging would be beneficial. The reviewer appreciated the presentation of unexpected results (home charging impact).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked the level of collaboration and coordination is appropriate.

Reviewer 2:

The reviewer observed appropriate collaboration with other national laboratories and external data sources.

Reviewer 3:

The reviewer said the team includes not only other national laboratories, but also several partners specifically to provide real-world data.

Reviewer 4:

The reviewer said yes, this shows the project lead and partners, but does not quite lay out who does what, exactly. The reviewer inquired were the results from RideAustin and Columbus, Ohio shared with the cities. The reviewer also wondered if there could be some sort of rate structure to improve the dead-heading on RideAustin. The reviewer also pointed out that as part of the project set-up, it did not quite detail out the difference between a taxi and ride hailing. The reviewer though this is more of a paper study as to how the different businesses operate—great for an MBA study project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked the project has clearly outlined next steps.

Reviewer 2:

The reviewer pointed out that the project has identified several areas for future efforts, focused upon upcoming changes in the underlying application areas. A number of additional questions have developed as the team progressed further into the research. The reviewer noted the project team is also developing relationships with other organizations who might be able to provide additional data to help answer these developing questions.

Reviewer 3:

The reviewer saw what the team has accomplished as good. The reviewer would like to see something more compelling for future research—whether it is engineering driven from a battery standpoint and charging standpoint—or if the author basically stops at Slide 11. The reviewer asked what compelling future research the author has in mind.

Reviewer 4:

The reviewer commented that proposed future research seems open-ended and is not well-defined.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that the project is relevant to determining charging infrastructure needs in response to future EV proliferation.

Reviewer 2:

The reviewer pointed out that the project is focused on attempting to determine infrastructure needs for privately shared vehicles, particularly based upon performance/range requirements and use patterns. This is particularly important for non-conventionally-fueled vehicles, in order to determine the potential energy savings/petroleum displacement by incorporating alternative fuel vehicles.

Reviewer 3:

The reviewer described this dead-heading for ride hailing as rather annoying, and asked if that percentage is acceptable.

Reviewer 4:

The reviewer remarked the project loosely supports DOE objectives by determining charging infrastructure requirements—but the reviewer was not clear what the action items will be once the project is complete.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that at this time, the resources appear sufficient. As additional questions arise, there may be a need for additional resources.

Reviewer 2:

The reviewer commented that the team has been able to find data resources to accomplish the project task.

Reviewer 3:

The reviewer commented resources appear sufficient.

Reviewer 4:

The reviewer noted that the project team spent $325,000 in FY 2018. The reviewer inquired what is compelling to keep adding to the team's future research.

Presentation Number: eems039
Presentation Title: Fuel Selection for Fully Automated, Commercially Owned Taxi Fleet
Principal Investigator: Timothy Lipman (Lawrence Berkeley National Laboratory)

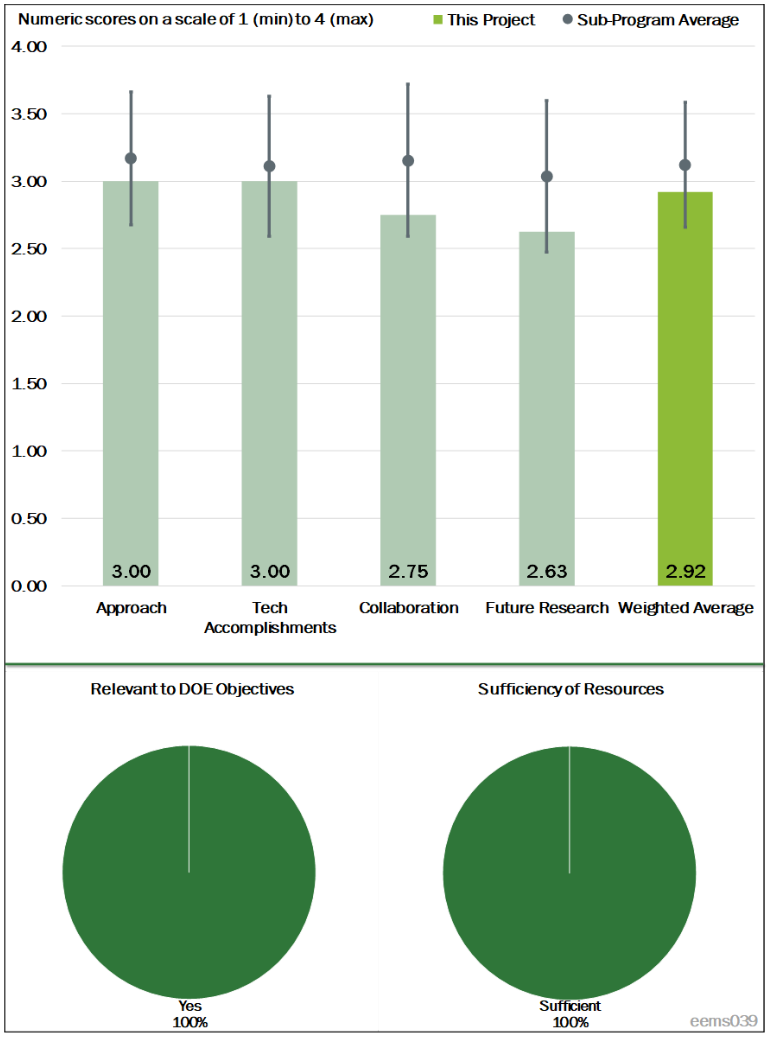

Figure 3-25 - Presentation Number: eems039 Presentation Title: Fuel Selection for Fully Automated, Commercially Owned Taxi Fleet Principal Investigator: Timothy Lipman (Lawrence Berkeley National Laboratory)

Presenter

Timothy Lipman, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said the approach is set up in a good way and is supported by logical goals and work plan. The reviewer found that this is a well-designed project.

Reviewer 2:

The reviewer remarked the project appears focused on answering the key questions related to incorporating AVs into fleets. The project team is using existing modeling modules where possible, and then adapting them to address the project's specific needs. The reviewer detailed that the key areas are market and infrastructure elements. One small concern is that right now the only comparison really going on is between plug-in electric vehicles and gasoline vehicles. The reviewer said it could be useful to include other alternative fuels with lower operating costs (particularly such as natural gas or propane) at some point.

Reviewer 3:

The reviewer said that using a BEAM-like agent-based system to test charging behavior appears to be a viable direction. The reviewer noted that Slide 8 suggested that a large part of the effort will be in modifying BEAM to ride-hailing/TNC markets and BEAM PEV. The reviewer said that it is hard to evaluate how much effort this takes; the former could be quite complex (to add ride-hailing origins-destination (O-D) pairs plus trip assignment algorithm). The later (BEAM PEV) seems already advertised on http://beam.lbl.gov/, so not sure what modifications the project needed. Slides 16-18 show some options. The reviewer asked if these options were done by the project, or by earlier BEAM developments. The reviewer also asked if the project chose one of these three options, and why. Still, according to the reviewer, updating BEAM for an AD and MaaS is an important effort, and one that deserves support. The reviewer said that the general direction is "very good," and seeing that was not an option, the reviewer chose the closest response to this on Question 1.

Reviewer 4:

The reviewer found this project rather confusing in its goals and approach. The goals mention the various options for fueling future taxi fleets made up of CAVs, yet EVs are the only ones analyzed. The authors mention gasoline as a topic for future study, but fuels such as natural gas or propane would offer potential lower costs and lower emissions. The reviewer noted that the authors show work that tries to evaluate different charging and energy storage options, yet it is not clear how their results would feed into anyone's decision-making process. The reviewer said the authors calculate an overall annualized investment that combines costs for the vehicles, charging stations, grid upgrades, and energy, yet each of these may be purchased by a different entity to that no one really cares what the total investment number really is. The reviewer said the authors show results for siting charging stations, yet it is not clear that the authors are taking into account the key deterministic parameters. The reviewer liked the fact that the work is focusing on real fleets (taxis) in real cities (New York City, and San Francisco), but the reviewer is not confident that it is addressing the right barriers or that the tools being developed are the rights ones to contribute to answering the questions that will be confronting decision-makers. The reviewer remarked the results regarding temperature dependence of charging time and energy use for EVs hardly seem to require a complex model. While the reviewer gave the researchers some not-insignificant credit for focusing on real systems, the reviewer thought the project team needs to clarify the questions it wants to answer and ask itself and other interested parties (fleet owners, city managers, etc.) whether these are the right questions.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer described that the team has been focused on refining its modeling tools, and then running different scenarios to identify anticipated infrastructure needs. More of the effort is currently focused on the demand element for integration into the BEAM model, using multiple approach concepts (including one iterative approach). The reviewer said that the team has been using real-world data to build their modeling knowledge base. In particular, one key element analyzed was charging performance at different ambient temperatures.

Reviewer 2:

The reviewer said that initial simulations of infrastructure cost and energy use are complete and results are encouraging. The reviewer was not entirely clear how the team will compare baseline fuel infrastructure to EVs.

Reviewer 3:

The reviewer remarked that, as previously mentioned, this updating of BEAM is important. The results on Slides 12, 13, and 19 are nice, but feel more an effort to debug the BEAM implementation as opposed to definitive answers. The reviewer thought that at this point in the project, that is no problem. The reviewer said that clearer statements on the simulation outputs are expected for next year.

Reviewer 4:

The reviewer referenced prior comments in Question 2. The reviewer is not convinced that the researchers are addressing the right questions in the right way, so it is hard to give a high score to the team's technical accomplishments. Most of the results that the authors showed, whether it is those regarding investment as a function of vehicle and charging station characteristics or those regarding temperature dependence of energy use in EVs, seem capable of being reached with relatively simple calculations and do not require complex models. The reviewer said that the authors seem to be developing the model for its own sake and not for the purpose of addressing real questions that are, or soon will be, vexing decision-makers.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the project includes collaboration among the key national laboratories working in this area. The reviewer commented it might have been nice to incorporate at least a few fleet operators to inform decision-making and planning, as well as perhaps infrastructure providers/utilities.

Reviewer 2:

The reviewer noted that Slide 22 seems to indicate there is some logic behind the collaboration efforts, and the reviewer trusted that is true. As with most of the EEMS projects, the reviewer thought the roles of the participants and the contributions of each to the overall goals could and should be much clearer.

Reviewer 3:

The reviewer observed that Slide 22 summarized collaboration. One has the feeling that collaboration (or perhaps high-level information sharing) "will take place," but the reviewer found that descriptions on Slide 22 are quite vague, e.g., "working with," "comparison with." INL appears to be involved, but the reviewer was not clear how. More specific collaboration details should be included by next year's AMR. The reviewer said the table showing interdependencies on the bottom of Slide 22 is nice, but it is not the same as collaboration.

Reviewer 4:

The reviewer observed very good coordination within the national laboratory community, but according to the reviewer the project needs industry collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted that there is a specific and rational plan for next steps to address the remaining questions, building upon previous results. Like other projects in this area, it appears that as research goes along, new questions arise, so there may be additional needs for future research.

Reviewer 2:

The reviewer reiterated that updating BEAM to these MaaS and AD scenarios is important, and should be continued. However, such tasks rarely have a linear relationship with time, so it may be hard to describe exactly what was done, and what exactly needs to happen. The reviewer understands and appreciates that challenge. Still, these slides do not give this reviewer a good sense of "how close to the end" the project is. It would be ideal to have more project reports provided to this reviewer. The reviewer expressed having no reason to think that good progress has not been made, and some tangible, more-clearly-relatable accomplishments will appear as we go forward.

Reviewer 3:

The reviewer said the presentation did not have enough discussion about future research needs.

Reviewer 4:

The reviewer commented future plans only talk about developing more detailed inputs for the model rather than presenting a plan with milestones and decision points. Without such markers, it is impossible to tell whether the work is progressing as needed to a logical goal or endpoint. The reviewer said that this may be the intent, to avoid critical assessment of the project. The future work hints at addressing more about vehicle characteristics, charging station characteristics, and fuel choices, yet it does not clarify how it will address any of those in a meaningful way.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer remarked the project is focused on simulating energy consumption and costs of new transportation scenarios, including comparing conventional versus alternative fuel options.

Reviewer 2:

The reviewer responded yes, and elaborated that BEAM is a DOE tool that needs to be updated to address modern questions of the interactions of AD and MaaS. This will be important in setting direction for energy estimations and other impacts of these new technologies.

Reviewer 3:

The reviewer said that both are addressed. The reviewer asked does vehicle automation improve the economics of an EV fleet when considering the different charging infrastructure needs, and what types of charging infrastructure planning will support AV operations in the future.

Reviewer 4:

The reviewer said that as with most of the EEMS projects reviewed, this project is aimed at dressing real questions about energy use and infrastructure requirements for future CAVs. However, it does not do so in a very clear way so the reviewer did not think it supports DOE objectives very effectively. The reviewer remarked if the authors took time to pose the critical questions more carefully, the project might do a better job of supporting the DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer responded that the resources currently appear sufficient, though there may be need to extend the project to answer new questions that are arising. The reviewer pointed out that no resources have been identified at this time to address such a scenario.

Reviewer 2:

The reviewer said that the resources seem to be sufficient based on the type of modeling being done, the number of people involved, and in comparison to other projects. However, according to the reviewer the presentation does not really identify any milestones because the work plan is not laid out in a logical, progressive manner that includes milestones and decision points. The reviewer reiterated that modeling real fleets in real cities is a plus, and the resources identified here should be sufficient to do some valuable work. However, per the reviewer, the project needs to have a better set of goals and a better work plan to assure the project spends funds properly.

Reviewer 3:

The reviewer said that it was hard to really judge this, as the slides list six people, but not how much of their time is consumed by this project.

Reviewer 4:

The reviewer said none.

Presentation Number: eems040
Presentation Title: Fuel Selection in Automated Mobility Districts/Dynamic Wireless Power Transfer Feasibility
Principal Investigator: Omer Omar (Oak Ridge National Laboratory)

Presenter

Omer Omar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

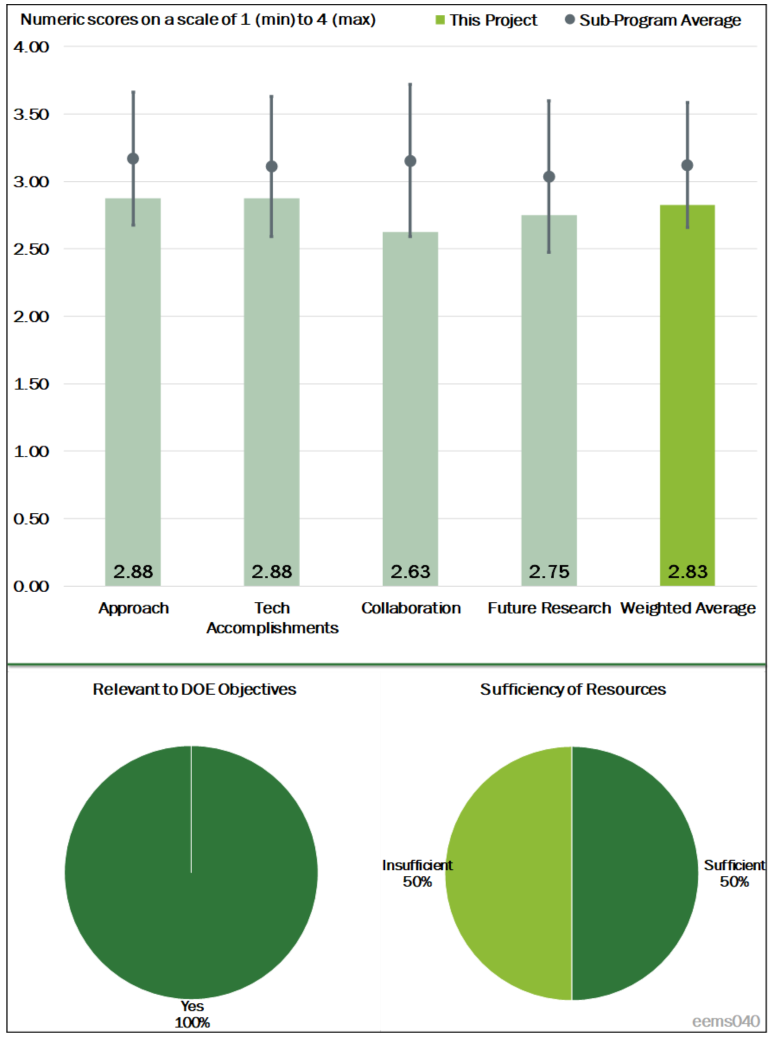

Figure 3-26 - Presentation Number: eems040 Presentation Title: Fuel Selection in Automated Mobility Districts/Dynamic Wireless Power Transfer Feasibility Principal Investigator: Omer Omar (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found that overall, the project is well-designed. The main barrier of obtaining real-world data does not appear to have a solution, which is a major concern, because the validity of the models relies on the performance of a new technology.

Reviewer 2:

The reviewer described that the outcome of this task is to produce a design guideline applied to an example test case scenario for the optimal deployment of dynamic wireless power transfer (DWPT) systems to support future roadway and electric power infrastructure planning. This is a notable and important outcome if it can be achieved. The reviewer said that the approach needs to include more input from transportation planning stakeholders to make it more realistic.

Reviewer 3:

The reviewer said that overall, the presentation lays out the optimization problem statement quite well, with a somewhat confusing example. The reviewer said please refer to comments in response to Question 4.

Reviewer 4:

The reviewer commented that the project is well-designed with supporting calculations. The 90% power transfer assumption should be reviewed to ensure that is the correct value and that no additional technical barriers exist with an implementation that delivers 90%.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that good progress has been made with respect to the development of power estimation, transfer efficiency, and track planning.

Reviewer 2:

The reviewer said very complete simulations and data provided to support the progress of overall project.

Reviewer 3:

The reviewer observed pretty good progress overall, but this reviewer does have some very specific comments about some of the reported work. Referring to Slides 11 and 12, in general, the reviewer is not a fan of providing so many significant digits in calculations. LIGO precision levels are not being discussed here, and four or five significant digits give a false impression about the accuracy of the calculations. The reviewer said that this stands in stark contrast to the assumptions on driveline efficiency and auxiliary power, which are rounded off to one or two significant digits.

The reviewer was also unsure why the UDDS cycle is being used as an example, especially when the test vehicles include a light-duty vehicle (LDV), a medium-duty vehicle (MDV), and an HDV, two of which are never subjected to a UDDS certification cycle. The reviewer said that if the purpose is to use this purely as an example, then perhaps that should be made clear in the very beginning.

Reviewer 4:

The reviewer described that what was presented were calculations regarding potential DWPT levels. The reviewer said this was not fully relevant, and there were no cost inputs for higher power systems. The reviewer noted that most of the technical results did not include the transfer efficiency. The reviewer found that accomplishments were incomplete and not really meaningful.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said good collaborative effort with INL and NREL.

Reviewer 2:

The reviewer said that a collaboration with ANL to determine vehicle energy use rates is good. Further collaboration with a partner than can provide data is essential for project success.

Reviewer 3:

The reviewer remarked there were only internal DOE collaborations. This project would require real-world input from transportation planners, from systems people, or from DWPT systems providers.

Reviewer 4:

The reviewer commented that the project needs external industry partners, especially to support the goal of establishing a plan for a wireless roadway. The reviewer remarked a partner from DOT or a civil engineering university program would provide benefit to the project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the proposed research is effectively planned given the barrier of lack of field data.

Reviewer 2:
The reviewer said that, because to this reviewer's knowledge there are no DWPT systems in use, the reviewer is unsure how analysis can be expanded to "real data." Perhaps the approach that will be used to achieve this should be spelled out in more detail. The reviewer thought that expanding the analyses to cover quasi-dynamic (quasi-static?) systems is definitely a worthwhile idea, because this would be the first step towards the implementation of any DWPT system. The reviewer remarked that the last deliverable, designing a more advanced DWPT system with improved efficiency, power transfer, and reduced emissions, is perhaps outside the scope of this project. The reviewer pointed out there have been other DOE-funded projects at ORNL that have looked at a similar goal.

Reviewer 3:
The reviewer remarked the future research needs to have additional input to make it fully meaningful. Expand collaborations and incorporate more understanding of systems and operational constraints.

Reviewer 4:
The reviewer referenced prior comments.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer agreed that this project supports DOE objectives, although the availability of power distribution and infrastructure may shape the priority as a long- or short-term study to pursue.

Reviewer 2:
The reviewer said the project supports all aspects of DOE wireless charging power objectives, except perhaps heavy-duty trucks.

Reviewer 3:
The reviewer expressed holding opinions about the efficacy of DWPT, especially in relation to other DOE supported technologies. As far as addressing the DOE objectives, the reviewer said yes, the project does support overall DOE objectives. The reviewer elaborated that DWPT could allow EVs to downsize their batteries, reducing their cost and improving their efficiency, range, etc., thereby paving (with coils) the way to make them more affordable.

Reviewer 4:
The reviewer said the concept supports DOE objectives, but it is not clear that the outcome will have any significant impact without adding a lot more stakeholder input, both technically and operationally.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that resources appear to be sufficient for the project.

Reviewer 2:
The reviewer said that this is primarily a theoretical exercise and does not require any hardware. The data to validate the models presumably came from separately funded projects. So, according to this reviewer it appears that the funding level is sufficient to execute this project successfully.

Reviewer 3:
The reviewer remarked that the project needs input from stakeholder resources to assure success.

Reviewer 4:

The reviewer commented add partners and conceptual scope for implementation in the future work.

Presentation Number: eems041
Presentation Title: Hardware-Focused Connected and Automated Vehicle (CAV) Research: Experimental Results and Benefit Analysis
Principal Investigator: Eric Rask (Argonne National Laboratory)

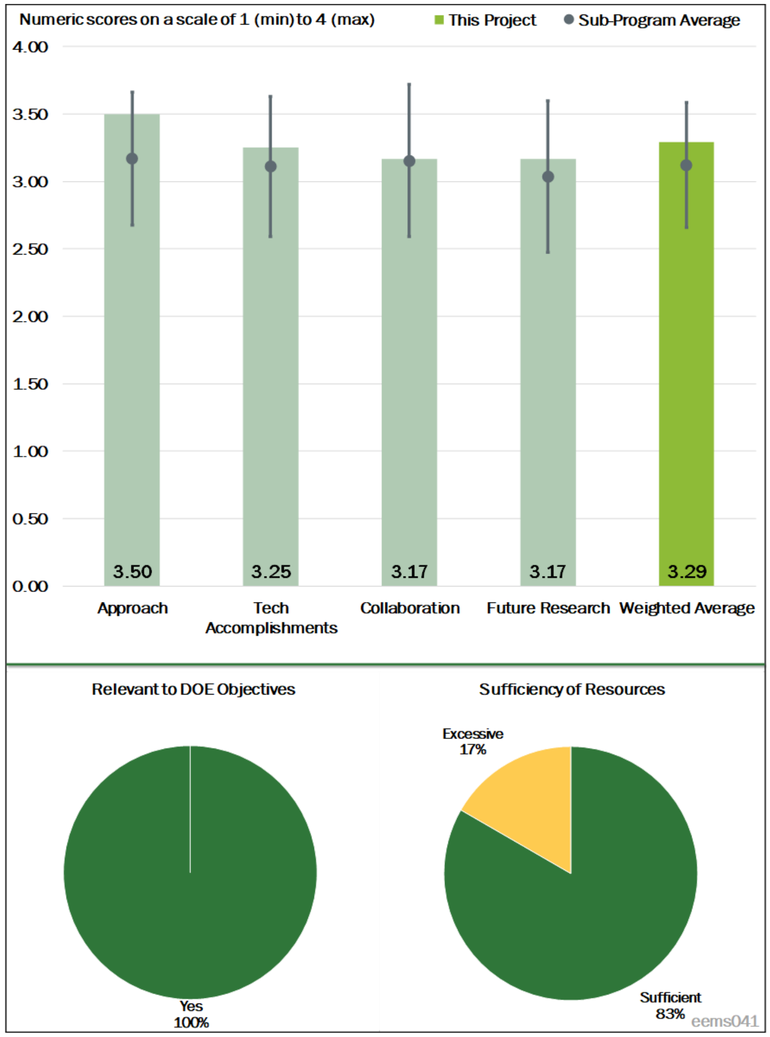

Figure 3-27 - Presentation Number: eems041 Presentation Title: Hardware-Focused Connected and Automated Vehicle (CAV) Research: Experimental Results and Benefit Analysis Principal Investigator: Eric Rask (Argonne National Laboratory)

Presenter
Eric Rask, Argonne National Laboratory

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer said excellent work in leveraging the available resources to answer questions about the impact of CAV-related technologies without actually having CAVs. The reviewer commended researchers for their ingenuity. Actual CAVs would be great, but the reviewer understands that the likelihood of obtaining some in this highly competitive R&D area is low.

Reviewer 2:
The reviewer observed a well laid-out approach with clarity.

Reviewer 3:
The reviewer remarked well-communicated plan, research thrusts, and project overview.

Reviewer 4:
The reviewer acknowledged that the barrier of obtaining repeatable, accurate, and objective data for emerging CAV systems is a large hurdle for those involved in this research area. The project does a formidable job of combining several parallel tracks of data to reach this goal.

Reviewer 5:
The reviewer liked this approach. This project also had significant funding. The reviewer did not see how the project spent money, whether on hardware, manpower, etc.

Reviewer 6:
The reviewer elaborated that this is an experimental dataset accumulation on currently available vehicles with in-market CAV elements. The reviewer noted how this is something that can form a baseline for evaluation of

current and future CAV technologies. The project collects data in normal ways for a new technology, and the project is developing libraries. The reviewer said the approach seems okay and is fairly straightforward.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented accomplishments are clear and on track.

Reviewer 2:
The reviewer said that progress is excellent. The ACC experimental results are complementary to the theoretical work being done in other projects.

Reviewer 3:
The reviewer really liked accomplishments on Slide 11, in relationship to ACC cycles showing fewer shifts. ACC operation shows expanded top gear utilization. However, the reviewer thought the project team needs to note is the components used for ACC, such as year, supplier, the software used (year and lines of code), transmission gears used, and explain a lot more what that means.

Reviewer 4:
The reviewer said that overall progress in delivering meaningful data is promising. There is room for improvement in identifying the baseline human driving assumptions and the corresponding variance to test data. In addition, according to the reviewer further work on the relationship between fuel economy improvement versus tractive energy reduction and powertrain operational changes would be valuable.

Reviewer 5:
The reviewer said that of the four complimentary research thrusts, the only question this reviewer came away with is how the chassis dynamometer control data will be used in future modelling efforts. The reviewer observed a very good presentation of results.

Reviewer 6:
The reviewer remarked that the project is focusing on the CAVs systems' data accumulation. The reviewer detailed that the project ran on a dynamometer, then ran on a track, then ran in the real-world, and compared resultant datasets.

The reviewer said the project is focusing on energy use rather than safety, and can take current vehicles and apply a robotic driver system. The reviewer asked can this add CAV capability in the future. The reviewer pointed out that the robot system is only for lab-based non-steering drive cycles, and this will not fill any need for automated development tools up to Level 5 in real-world test environments. The reviewer remarked ACC removed shifts from the F-150 should not be a surprise. The big engine can maintain speed in a single gear, and that is good programming from a drivability perspective.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented existing collaborations with ANL/DOE/SMART Mobility Consortium are good. The reviewer recommended future collaboration with similar research teams and/or original equipment manufacturers (OEMs) for data validation.

Reviewer 2:
The reviewer said good work and coordination among the partners.

Reviewer 3:
The reviewer observed good collaboration across national laboratories and academia.

Reviewer 4:
The reviewer thought that it would be nice to see who is presenting what, perhaps in a RASIC chart, or in a flow chart for data.

Reviewer 5:
The reviewer remarked definitely an in-house program with no industry collaboration.

Reviewer 6:
The reviewer said none.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
This was probably one of this reviewer's favorite presentations. Eric Rask showed not only enthusiasm for the project, but also competency. The reviewer thinks the author is just scratching the surface here for how ACC+ (the reviewer put + in there as technologies are moving quickly) can improve energy usage, and even potentially change the design of say, mechanical components in the powertrain. The reviewer does think the author has to be careful to outline what components, cameras, radar, and software are being used.

The reviewer suggested that the PI catch up with Karl Heimer, who puts together the Cyber Auto Challenge, which SAE sponsors; and the PI puts together the Truck Cyber Challenge sponsored by TARDEC and others in the heavy-duty industry. Also, the reviewer pointed out Ryan Gerdes at Virginia Tech is doing some great work on cyber relating to ACC+.

Reviewer 2:
The reviewer observed a comprehensive list of potential future activities that appear essential.

Reviewer 3:
The reviewer commented that the general direction is good, and would be strengthened with more specifics.

Reviewer 4:
The reviewer commented a tighter integration with the DOE modeling and simulation toolchain is a valuable deliverable. The reviewer said that correlating the CAV benefits to physics would enable parameterization for downstream models and greater capability of the toolchain.

Reviewer 5:
The reviewer stated the project is pretty much planning to do higher fidelity versions of what has been done and run new drive cycles.

Reviewer 6:
The reviewer said detail plan for future work.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer loved this and commented that a combination of real world testing, modeling, as well as understanding cyber and how all these systems interact will inform how to optimize for energy improvement.

Reviewer 2:
The reviewer said yes, it is an essential deliverable in CAV development.

Reviewer 3:
The reviewer described that the project is needed for validation and exploration of new technology at the vehicle level. The reviewer said the project is useful for assessment of theoretical results from other tasks, and there is potential to gain insights that can inform other work.

Reviewer 4:
The reviewer said the project has value to mobility and vehicle connectivity.

Reviewer 5:
The reviewer agreed yes, especially for light-duty. The reviewer would have liked to see an integration of HDVs in the data collection.

Reviewer 6:
The reviewer agreed it is relevant to the DOE's stated objectives of understanding how new technologies can affect fuel use and reduce waste.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said resources are in-line with the project scope.

Reviewer 2:
The reviewer agreed that the project appears to be on track with current resources. Given uncertainties in experimental work, it is hard to say if the resources are sufficient.

Reviewer 3:
The reviewer found that resources are sufficient as long as Level 3-Level 4 sensors are within budget for future work.

Reviewer 4:
The reviewer pointed out that this was a big dollar project. Please carefully outline how the project spent money, and what needs to be done, dollar wise as well for future research. The reviewer also suggested please also reach out to industry as money is being spent there as well. With telematics and sensors, the authors might be able to determine wear on parts as well.

Reviewer 5:
The reviewer questioned the value of performing tests such as these in a national laboratory environment, relative to the resources required for it.

Reviewer 6:
The reviewer said none.

Presentation Number: eems042
Presentation Title: High-Performance Computing (HPC) Enabled Computation of Demand Models at Scale to Predict the Energy Impacts of Emerging Mobility Solutions
Principal Investigator: Jane Macfarlane (Lawrence Berkeley National Laboratory)

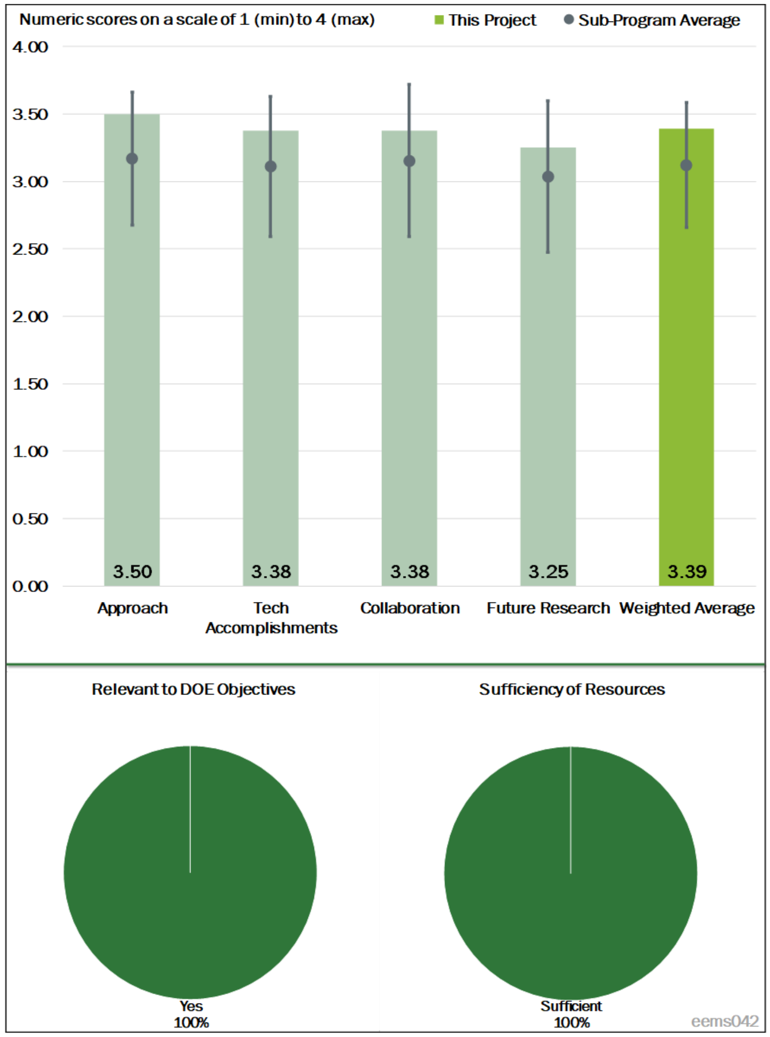

Figure 3-28 - Presentation Number: eems042 Presentation Title: High-Performance Computing (HPC) Enabled Computation of Demand Models at Scale to Predict the Energy Impacts of Emerging Mobility Solutions Principal Investigator: Jane Macfarlane (Lawrence Berkeley National Laboratory)

Presenter

Jane Macfarlane, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer agreed that a distributed vehicle energy consumption estimation is a great approach to developing a robust scalable energy consumption monitoring system.

Reviewer 2:

The reviewer remarked good approach.

Reviewer 3:

The approach is a logical framework for creating a large-scale modeling methodology that allows application of multiple different existing traffic assignment models within an HPC processing environment through a uniform data input/output format. The reviewer characterized this as important work.

Reviewer 4:

The reviewer said the project to address the complexity of urban-scale integrated transportation networks clearly describes the technical challenges and potential solutions. Previous solutions have focused on travel time and not on energy use (although the two are related). The reviewer pointed out that information-aware routing is a significant challenge not just in the modeling and simulation but also in realistic implementation in urban real-world scenarios. The project recognizes these challenges and proposes to bring HPC capabilities to solve the traffic assignment problem.

The reviewer described that the project formulation is guided by well-thought out questions such as the need for information sharing and automation of vehicles, the need for navigation apps, the appropriate responses to accidents, emergency situations and so on. Recognizing the computational intensity of the traffic assignment problem, HPC resources are proposed as a computational platform to solve the problem. The reviewer thought this seems appropriate, but does bring up the question of long-term implementation in realistic transportation networks that have distributed computing resources and the need for millisecond timescale decisions from real vehicles on the road; it is therefore unclear if the lessons learned from HPC-based solutions may be easily implemented in real-world scenarios. The reviewer pointed out that considering that distributed computing architectures in transportation networks (on vehicles, roadside computing etc.) differ from HPC architectures, questions related to efficient data movement for timely computations and decision making are yet to be addressed. However, given the timeline of the project, and that it is only 5% complete, these issues and concerns may yet be included in the project formulation and planning. The reviewer found that the project is therefore well-designed and feasible from a research perspective but is probably not well-designed from the long-term view of implementing the solution in realistic scenarios.

The reviewer noted that the technical approach suggests the creation of a standard process for ingesting map data at scale on distributed platforms. The proposal also refers to the implementation of a distributed solution algorithm for static user equilibrium formulation and the dynamic traffic assignment solution. The reviewer said that if the proposed distributed algorithms can emulate technical solutions for real-world distributed computing resources on vehicles and in data centers used by vehicle OEMs, then better alignment with real-world needs and scenarios is possible.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said the project just started.

Reviewer 2:
The reviewer remarked results to date look good.

Reviewer 3:
The reviewer commented work appears to be on schedule.

Reviewer 4:
The reviewer detailed that the project started in April 2018 and is therefore only 5% complete. The project describes the formulation of user equilibrium for energy using a comprehensive modal emission model that is graphically represented as a plot of fuel consumed in grams per mile as a function of average speed in miles per hour. The project obtained these data from previous work. The reviewer remarked a fuel consumption density for UE and the System Optimal case is also depicted graphically to illustrate the challenges that remain to be addressed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer described that the project team consists of LBNL and the Connected Corridor, the University of California (UC)-Berkeley, CalTrans, Los Angeles (LA) Metro, and HERE for mobility data. The reviewer noted that HERE provides the GPS data for the Connected Corridor region.

The reviewer said that the team appears to have an excellent collaboration and coordination effort. The reviewer elaborated that the combination of infrastructure data and mobility data combined with the HPC and distributed computational resources has the potential to lead to a successful outcome for this one-year project based on previous demonstration of collaboration and coordination on a related project.

Reviewer 2:
The reviewer said good team.

Reviewer 3:
The reviewer noted strong collaboration amongst partners.

Reviewer 4:
The reviewer remarked in addition to the importance of this work among the DOE national laboratories, the participation of the Los Angeles agencies that have provided the data for the study corridor is also key collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that future research is relevant.

Reviewer 2:
The reviewer pointed out that planned deployments are critical.

Reviewer 3:
The reviewer described that the proposed research for the future aims to include models that represent multiple driver classes at large-scale. These are to account for app-routed and non-routed drivers. The reviewer said that the energy impact of these different driver routing profiles is planned. Further, the team has planned parallel algorithms for dynamic traffic assignment and under various scenarios to include instantaneous travel, historical travel time forecast, and so on.

The reviewer noted how app-routed drivers use the cloud for their real-time app information. The reviewer was unclear how the proposed effort plans to integrate cloud-based information that may belong to private vendors such as Google, Apple, Waze and others. Route suggestions provided by these apps in real-time are sourced from the cloud; the computational resources, architectures, computer programs and so on that reside in those clouds and the vehicle or device, are inaccessible to the public, so the reviewer was unclear how app-routed information is planned to be integrated in a future solution based on HPC. The reviewer identified that this risk needs mitigation.

Reviewer 4:
The reviewer pointed out that a schedule risk will occur when extending the processing to a large-scale modeling with dynamic trip assignment.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said the project can save fuel and prevent congestion.

Reviewer 2:
The reviewer said that project goals are relevant to helping DOE determine traffic dynamics in real time and in a robust fashion.

Reviewer 3:
The reviewer agreed that the work is central to the objectives of developing HPC processing capabilities for large-scale modeling of energy use.

Reviewer 4:

The reviewer noted that the project has significant relevance for DOE and in particular VTO's mission of energy-efficient vehicle mobility. HPC-based solutions to obtain energy use data from vehicles in urban transportation networks are valuable. However, according to the reviewer technical approaches that can address the challenge of energy-efficient mobility through traffic assignment/route planning are even more important in a future where vehicle-to-vehicle connectivity is going to be ubiquitous and cloud-based software solutions will be critical in guiding traffic in congested cities. The reviewer noted that route optimization has a positive dual impact in saving travel times as well as reducing energy use by vehicles in transportation networks.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented the priority of HPC modeling development justifies the application of full resources.

Reviewer 2:

The reviewer said that resources are sufficient.

Reviewer 3:

The reviewer agreed that resources seem aligned with project activities.

Reviewer 4:

The reviewer remarked resources for this one-year project seem adequate. The proposed objectives may be met considering the resources (in the form of data) that the various team partners provide to develop the foundations of the project. The reviewer pointed out the framework that is built through this project may be scaled for future use with appropriate modifications and changes based on real-world use cases.

Presentation Number: eems043
Presentation Title: Mobility Behavioral Responses to Transportation Network Company Services
Principal Investigator: Alejandro Henao (National Renewable Energy Laboratory)

Presenter

Alejandro Henao, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked this EEMS project does the best job of those reviewed of defining an objective, defining the right research questions to address that objective, and posing those questions in a clear and concise manner so that anyone can understand what is being done and why. The reviewer commented that other EEMS projects could learn from this one about how to formulate a meaningful goal, an approach to fulfilling it, and a presentation to explain it clearly. The reviewer noted that Slides 6 and 7 do a good job of stating the objective and communicating the research questions that will be explored in an attempt to reach the objective. The reviewer described that the only reason this score is not higher is because the reviewer believed there are additional worthwhile questions that this research could address. The reviewer elaborated this is not meant as a criticism but rather as encouragement to do more.

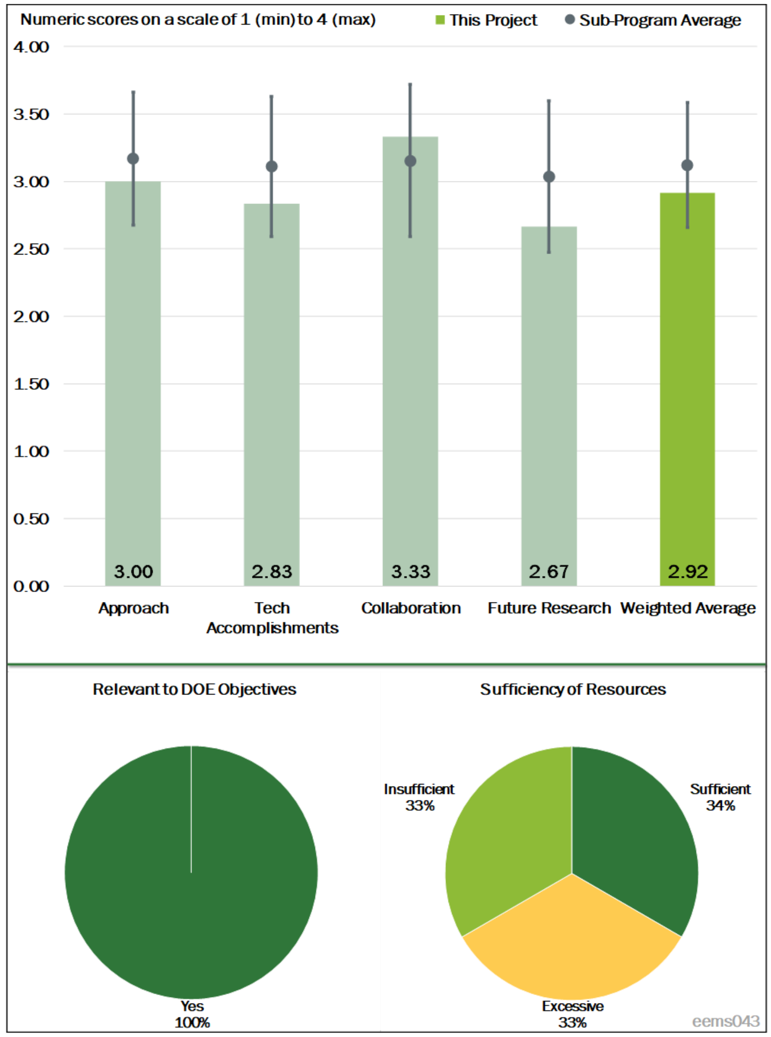

Figure 3-29 - Presentation Number: eems043 Presentation Title: Mobility Behavioral Responses to Transportation Network Company Services Principal Investigator: Alejandro Henao (National Renewable Energy Laboratory)

Reviewer 2:

The reviewer said that some elements of the approach are sound, such as gathering the data around TNC penetration and vehicle ownership. However, the approach is at least somewhat flawed with respect to analyzing correlations and implying they are causations. The reviewer spared the review with the volume of text written on this topic, but suffice it to say, even if vehicle model year increases as TNC availability increases, that is mostly just an interesting coincidence rather than one causing the other. In addition, even if it were a causation scenario, it still would be unclear which direction the causation was. Further, this reviewer inquired as to whether increasing the TNC availability really leads to vehicle model year increases, or whether vehicle model year increases lead to more TNC availability. The reviewer cautioned that this type of error can ultimately lead to very bad policy that expects a certain outcome by playing with the inputs, when in fact something very different and unanticipated actually happens.

Reviewer 3:

The reviewer was not clear why the project chose two areas (TNC deadheading and vehicle ownership) from Slide 9 to focus on first. There is not a clear connection between these two. Also, according to the reviewer there was not a mention of looking to previous research and how that informed the study. The reviewer cited as an example there are studies out there that have looked at mode shift impacts from TNCs.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that based on the presented schedule, the project is on track. However, the schedule only addresses two of the four objectives listed in Slide 6.

Reviewer 2:

The reviewer said that the accomplishments are very preliminary, and do show some promise for some interesting analysis. However, the reviewer said that the correlation versus causation problem is a fundamental flaw that needs reconsidering before any more progress is made. As examples, the reviewer cited a Slide 12 text box, “No significant effect!” and a Slide 13 text box, “Effect on unemployment changes!” The accomplishments themselves need reconsideration. The reviewer pointed out that taken at face value, these conclusions could imply that in order to solve unemployment across America, policies to increase TNC presence should be implemented. The reviewer for one is quite skeptical of that in a vacuum.

Reviewer 3:

The reviewer remarked the research team is producing results that seem valuable and address the research questions appropriately. Slides 12 through 17 communicate some early results and analyses in a relatively clear manner. The reviewer noted how the researchers draw some conclusions that are revealed by the data, which can be revised or challenged later as more data become available. The reviewer elaborated that this score is not higher mainly because it is still early in the project (25% complete) and because the amount of data the team has been able to capture is limited. The reviewer pointed out that more data and more time will likely lead to more conclusive results and a higher score.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found that the collaboration is the bright spot for this project. With what looks like strong partnerships between two national laboratories, a university, and the private sector (Uber already and others in development), the end results based on those involved could rise to outstanding in time. The reviewer also noted that collaboration could rise to outstanding with bringing in other government agency experts (DOT, etc.).

Reviewer 2:

The reviewer found that the role of collaborators is clear. The reviewer asked if there has been any collaboration with other metro areas to share their experiences and research done on TNC impacts.

Reviewer 3:

The reviewer pointed out that Slide 19 does a pretty good job of defining which team member is doing what. The reviewer thought this could be expanded and enhanced. However, there seems to be evidence that each team member is contributing based on the collection and analysis of the data and the firm conclusions that are drawn from the analyses. Still, this reviewer would like to see the presentation provide more details on what each team member is doing and perhaps provide an example of how data are collected, cleansed (by whom), transferred, and analyzed. The reviewer thought that this would provide more insight on whether all team members are contributing appropriately or whether one or two are dominating the efforts. But without this level of detail, the results still seem to indicate it is reasonable to conclude there is effective collaboration and coordination going on.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted how Slide 21 seems to identify some worthwhile tasks. What is lacking is a logical plan with decision points and alternate pathways. This may be difficult to define for this type of project, but this research team seems quite capable in defining goals and research questions and approaches to answering them. The reviewer thought the team should be able to define a prime path and alternatives that show a logical progression toward the overall DOE goal. The reviewer does not want to provide advice where it is not needed or is impossible to follow, but it seems to the reviewer that this research team might benefit from talking with companies or individuals who have been involved in the siting of nuclear power plants (NPPs). Siting an NPP requires extremely thorough data collection and analysis of all the people that live, work, and commute within a 50-mile radius of the plant location. The reviewer described that these firms somehow collect data on every homeowner and business within that radius and every car that passes through that area. Then the data are analyzed within concentric rings of 5- or 10-mile width and within pie-shaped wedges from zero to 50 miles. The reviewer thought that the sources of data and the analysis techniques might offer some suggestions for future research by this team on mobility in a specified area. Just a thought. But, per the reviewer, this team is doing good work and mainly needs to add specificity, structure, and detail to the worthwhile tasks identified on Slide 21.

Reviewer 2:

The reviewer commented that this is really where cause and effect issues need to be sorted out. As is, there is still a line mentioning, “Analyze effect of TNC entry on vehicle ownership by ZIP code,” which this reviewer is not confident will be properly pursued. The reviewer acknowledged that the broader goal of investigating TNC effects on energy use is noble and important, and hopefully some of the methodology will yield defendable results in this area to inform other research areas.

Reviewer 3:

The reviewer pointed out that Slide 9 seems to list all of the components to be researched. The reviewer inquired if the intent of the project is to address all of these items, and if so, it is not consistent with what is presented in Slide 21 for proposed future research.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said yes, it is attempting to directly address energy use impacts from TNCs.

Reviewer 2:

The reviewer said that the high-level, overarching goals of this project do certainly support DOE objectives for understanding how energy use can be reduced, and in this case by TNC presence.

Reviewer 3:

The reviewer pointed out that understanding the impact of TNCs on energy use and mobility is a stated goal of DOE, and this project does a better job than most others of addressing that goal in a meaningful way. The reviewer thought the project is mainly hampered by the lack of relevant data, which argues for even more effort on finding and collecting more data from more sources.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked the research team seems to be producing good results with the resources provided, and the funding seems to be level from year to year, so this reviewer has to assume it is adequate. However, because this team is doing good work and is clear in their approach, the reviewer would recommend applying additional resources to this research through this team IF the team thinks it could apply the additional funds effectively without losing focus.

Reviewer 2:

The reviewer said that the resources are potentially insufficient as there is quite a bit of future work proposed and some hinted at, but the reviewer was not clear it will happen. The reviewer remarked if all of the potential proposed work will be tackled, then more resources may be needed.

Reviewer 3:

The reviewer commented that the budget does seem quite high for the work and direction the work is taking, particularly given the need to regroup on the approach (in this reviewer's judgment).

Presentation Number: eems044
Presentation Title: Estimation of Potential National Benefits of Advanced Fueling Infrastructure Deployment
Principal Investigator: Joann Zhou (Argonne National Laboratory)

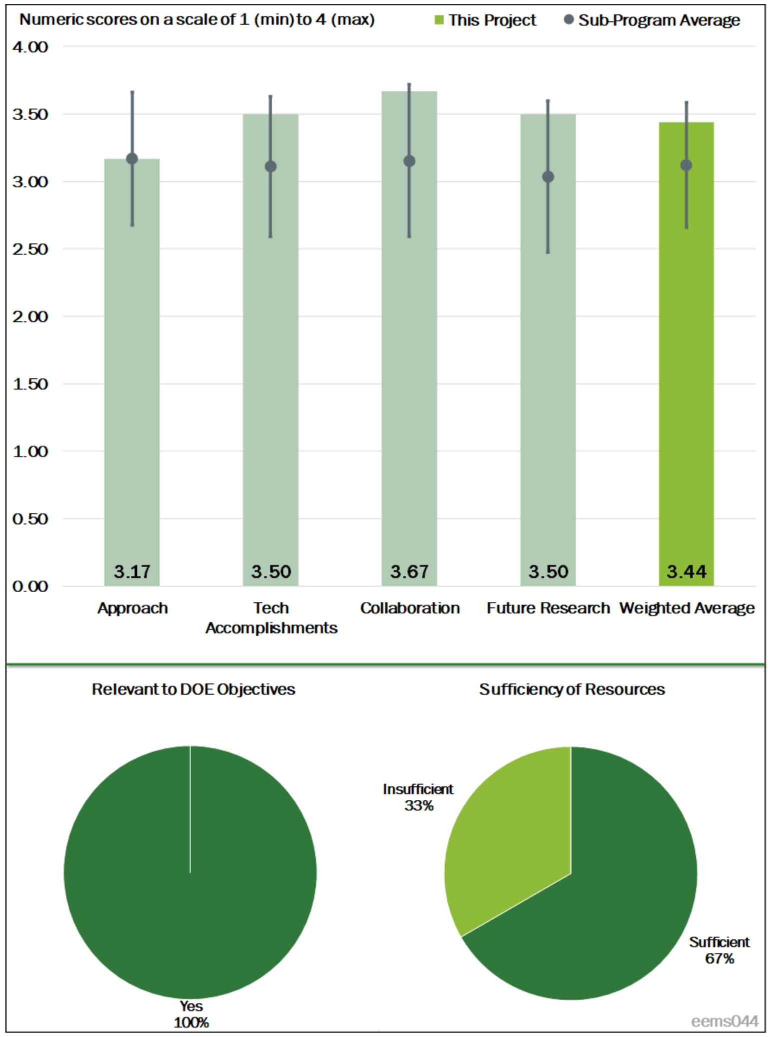

Figure 3-30 - Presentation Number: eems044 Presentation Title: Estimation of Potential National Benefits of Advanced Fueling Infrastructure Deployment Principal Investigator: Joann Zhou (Argonne National Laboratory)

Presenter
Joann Zhou, Argonne National Laboratory

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer said that this project leverages regional transportation analysis for Columbus, Ohio to estimate national level impacts of infrastructure support in reducing transportation sector energy consumption.

Reviewer 2:
The reviewer noted that the approach has some challenges in terms of how the results can be interpreted. The net impact of using new mobility services depend on how people respond—specifically, are people less likely to own and use a personal ca. Similarly, the infrastructure piece does not seem to have any economic component. The reviewer said that the availability, locations, price, and nature (direct current fast, Level 2) of charging will have an effect (potentially a major one) on the economics of mobility services. Even for a scenario-based approach, this should be considered. As far as the reviewer could tell from the poster, the Market Acceptance of Advanced Automotive Technologies (MA3T) model can account for vehicle adoption, but not between modes, which could be a much larger effect.

Reviewer 3:
The reviewer remarked there are still a lot of components of this research that are left somewhat unanswered by the presentation. The reviewer cited how will shared EV deployment look in rural versus urban areas. The reviewer asked besides fueling, what are the other factors that will determine what the ramp-up for EVs will be, and is the amount of unoccupied miles in ride-hailing vehicles going to factor into the potential energy savings.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that results presented had a clear story to tell regarding the marginal benefits of charging infrastructure with regard to reducing energy consumption.

Reviewer 2:
The reviewer noted very nice progress, and appreciated the multiple scenarios. The reviewer said the DC-fast charge results are limited in interpretability because the impact on new mobility is unclear.

Reviewer 3:
The reviewer reiterated there are still some questions that need to be fleshed out and responded to.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said good collaboration given the project size.

Reviewer 2:
The reviewer noted that there is evidence each of the partners have made significant contributions to delivering strong project results.

Reviewer 3:
The reviewer thought the project could benefit from applying some of their analysis to data from applicable cities to see how real-world impacts may affect findings.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said the future work is refining the analytic results by investigating regional variations in key independent variables. This work will increase the accuracy of the model estimates.

Reviewer 2:
The reviewer commented yes, multiple avenues to explore, which will nicely address some of the questions posed earlier.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer observed a clear connection to multiple DOE mission areas.

Reviewer 2:
The reviewer said that this work directly supports DOE's objective to measure the energy impacts of advanced mobility concepts and technologies. This work produces clear quantitative measures of shared mobility and supporting charging infrastructure on energy consumption (national level).

Reviewer 3:
The reviewer remarked it will be critical to understand the energy impacts of shared connected and automated vehicles, which have the potential to increase energy use or decrease it significantly if implemented in the right fashion.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that based on discussions with the ANL staff member that presented the project overview at AMR, it may be appropriate to increase the ORNL funding for this project. ORNL does a lot of work to produce data inputs that feed the analytic models. The reviewer remarked that increasing the ORNL funding by $50,000 per year would provide sufficient funds for this work.

Reviewer 2:

The reviewer said that project resources seem appropriate for scale.

Reviewer 3:

The reviewer said that the funding level appears to be appropriate for remaining work.

Presentation Number: eems045
Presentation Title: Focused Validation of Select SMART Simulation Activities
Principal Investigator: Erik Rask (Argonne National Laboratory)

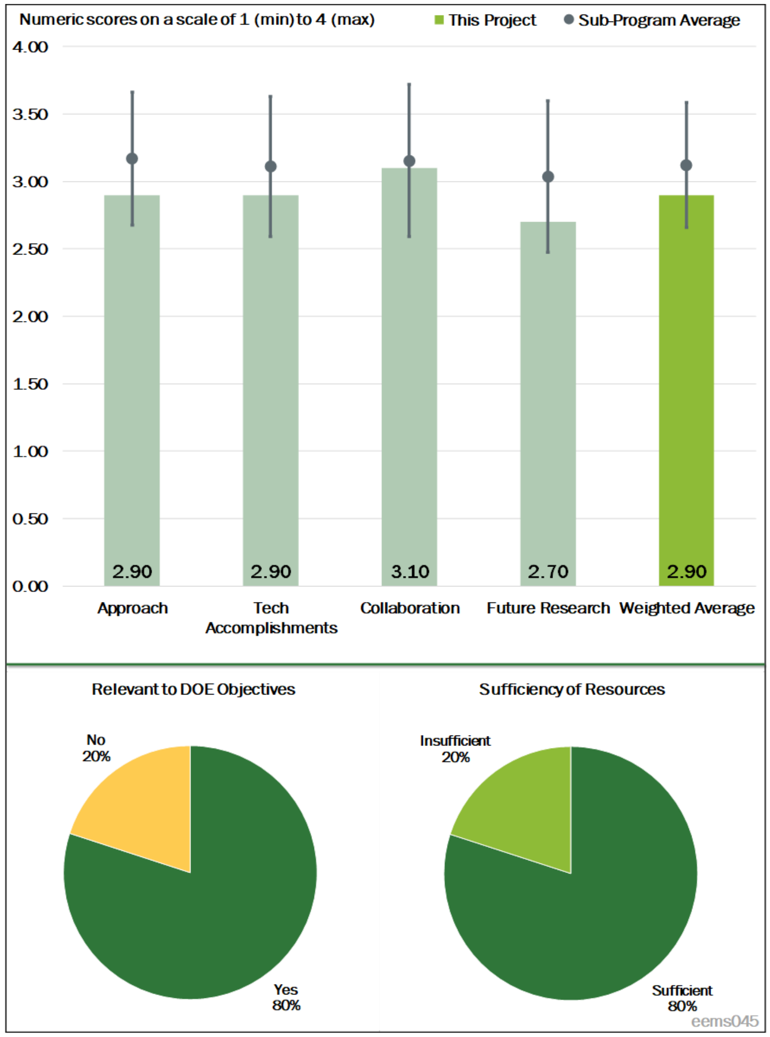

Figure 3-31 - Presentation Number: eems045 Presentation Title: Focused Validation of Select SMART Simulation Activities Principal Investigator: Erik Rask (Argonne National Laboratory)

Presenter

Erik Rask, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer applauded the approach taken for ingenuity in making do with what is available from existing resources, inasmuch as CAVs are not exactly readily available.

Reviewer 2:

The reviewer observed a very useful approach to validating theoretical work. The reviewer thought the project could benefit from an approach that will be built on as more comparisons are done—eventually researchers would want a library of theoretical versus measured that will help retrain models and identify what works best in real-world approaches.

Reviewer 3:

The reviewer believed that this project was simply a way to fund a dynamometer lab. The premise of replicating the analysis data using the dynamometer is okay, but it did not seem extremely valuable. The reviewer pointed out that this was a low-cost project however.

Reviewer 4:

The reviewer observed no issues.

Reviewer 5:

The reviewer’s biggest concern is that this was poorly presented at the poster session.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said that technical accomplishments are clear. The illustration of what has been done is quantified.

Reviewer 2:
The reviewer observed good progress and results, especially at the given project scale.

Reviewer 3:
The reviewer said that given the resource limitations, the progress is good. The reviewer understood that vehicles developed to the operational level required to demonstrate certain CAV features may be beyond the resources and budget available, but would be more effective tools.

Reviewer 4:
The reviewer stated that the project seems to be on schedule, but for what was unclear to this reviewer.

Reviewer 5:
The reviewer is unsure if the project was initially poorly set up, but it seems that way. The reviewer cited a lot of partners/stakeholder, a minimal budget, and too many barriers noted.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer observed good collaboration among the different national laboratories, with the team sharing data and performing testing and simulation.

Reviewer 2:
The reviewer noted good leveraging of other EEMS data.

Reviewer 3:
The reviewer said that partners are national laboratories, which is good and leverages available support. The reviewer prescribed that snagging an industrial CAV partner would be an outstanding development.

Reviewer 4:
The reviewer was unable to tell the level of collaboration.

Reviewer 5:
The reviewer observed lots of names on Slide 2, for Partners/Stakeholders, but, still not much data per the author's "Barriers."

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer saw a good overview of the remaining work.

Reviewer 2:
The reviewer asked if the project team could include some future work to allow this method to be reproduced and scaled to other EEMS topics.

Reviewer 3:

The reviewer found that future work is somewhat limited by what can be done with what is at hand. As with Question 6, an industrial CAV partner could be a very helpful addition to the work that can be done in this project.

Reviewer 4:

The reviewer thought that Slide 6 notes: "Research underway into sample rate requirements and filtering strategy." The reviewer recommended talking to Geotab, which has a tremendous amount of telematics data. Understand what you can and cannot sample, and combine pieces of data based on sensors. After that conversation, perhaps there will be more opportunities here for future research.

Reviewer 5:

The reviewer said that answers about the project left this reviewer wondering how it was proceeding today versus how it much it may proceed in the future. The reviewer commented not impressed.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said the project has value to developing profiles based on data.

Reviewer 2:

The reviewer remarked clear relevance to EEMS objectives.

Reviewer 3:

The reviewer found that this project is very useful because it can help answer key questions about the real-world limitations of CAV operating strategies.

Reviewer 4:

The reviewer agreed yes, this supports DOE, but the reviewer recommended the team please go back and evaluate project objectives here and rethink it.

Reviewer 5:

The reviewer did not see the relevance or value of this project to the program.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

This reviewer's impression was that more can be done if additional resources are made available.

Reviewer 2:

The reviewer said that resources seem appropriate for this effort.

Reviewer 3:

The reviewer observed no issues.

Reviewer 4:

The reviewer said it was hard to say, but the team should wrap up the project and move on to more relevant research that could result in real-world outcomes.

Reviewer 5:

The reviewer thought the team failed to demonstrate any results considering the resources allocated.

Presentation Number: eems046
Presentation Title: Understanding Connected and Automated Vehicles in Automated Mobility Districts
Principal Investigator: Matt Shirk (Idaho National Laboratory)

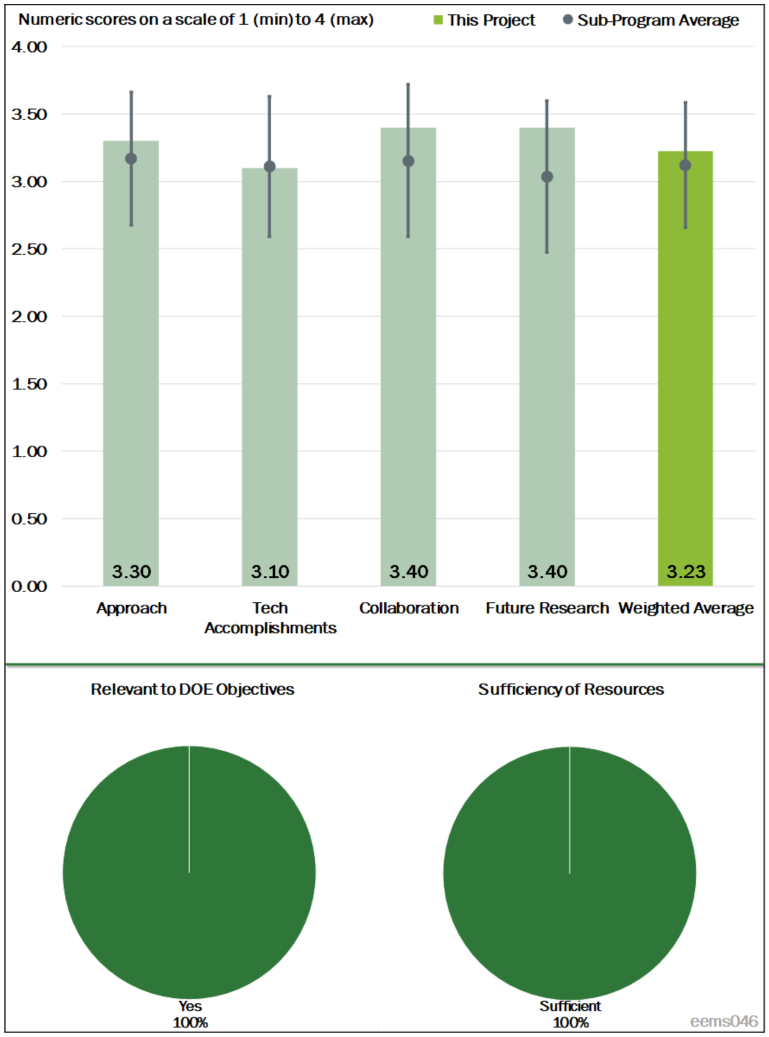

Figure 3-32 - Presentation Number: eems046 Presentation Title: Understanding Connected and Automated Vehicles in Automated Mobility Districts Principal Investigator: Matt Shirk (Idaho National Laboratory)

Presenter

Matt Shirk, Idaho National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the project has a well-thought approach towards understanding CAVs in AMDs.

Reviewer 2:

The reviewer detailed that the proposed approach is to identify AMD/CAV pilots and instrument them to get real data. The reviewer found that this is a sound approach.

Reviewer 3:

The reviewer commented a good outline of the approach and objectives.

Reviewer 4:

The reviewer said the approach is very appropriate for this stage of the project.

Reviewer 5:

The reviewer observed that it is a great idea to collect energy data from pilots, and the project could be improved by incorporating some data on the most important factor for the success and energy impacts of these projects—occupancy. The reviewer pointed out that the direct energy use is a good component but will not mean much on its own.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said the team has made significant progress in all aspects of the project to date.

Reviewer 2:

The reviewer remarked accomplishments were clear and on track.

Reviewer 3:
The reviewer said this is appropriate for this stage of the project.

Reviewer 4:
The reviewer detailed that CAV pilots have been identified and instrumentation packages have been prepared for field deployment. These include charging hardware energy meters and 10 Hertz (Hz) GPS interfaced to controller area network data loggers.

Reviewer 5:
The reviewer said progress (identifying pilots and planning) seems a bit short for being halfway through the project. Data collection and management will be huge challenges, so the reviewer hoped the work can accelerate going forward.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer observed good collaboration across teams and data sources.

Reviewer 2:
The reviewer said close coordination and use of data among the partners.

Reviewer 3:
The reviewer said it is apparent that the different organizations have distinct, complementary roles that can help the project succeed.

Reviewer 4:
The team has shown good coordination with INL, NREL, the University of Michigan, and the State University of New York-Buffalo/New York State Energy Research and Development Authority.

Reviewer 5:
The reviewer observed increased collaboration, and utilization of synergies among the various national laboratories has improved from the past, but the project has more potential to leverage their research and resources within the EEMS program

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the project is on time and approaching the final phase.

Reviewer 2:
The reviewer said that there is a solid plan for FY 2018 to achieve the remaining challenges and barriers.

Reviewer 3:
The reviewer said that this is appropriate for this stage of the project.

Reviewer 4:
The reviewer detailed that the plan is to continue data collection, merge vehicle and charging data, and refine analyses as appropriate.

Reviewer 5:
The reviewer said that there is clearly a lot more to do and results will be useful if they can be pulled off.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted that the project present opportunities to understand vehicle usage and energy consumption by CAVs operating in an AMD, so it is relevant to DOE's mission and objectives.

Reviewer 2:
The reviewer remarked getting real-world data on CAVs will be useful for validating models and understanding trends.

Reviewer 3:
The reviewer said there is value towards understanding the ways to improve energy efficiency.

Reviewer 4:
The reviewer said the relevance is clear.

Reviewer 5:
The reviewer said the potential for this project, and the overall EEMS program, are crucial to meeting objectives of energy efficiency solutions and decisions made by government and private industry to make informed decisions.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said resources seem appropriate.

Reviewer 2:
The reviewer said that the project has sufficient resources to accomplish the milestones.

Reviewer 3:
The reviewer commented this is appropriate for this stage of the project.

Reviewer 4:
The reviewer said that resources are adequate for the stated plans.

Reviewer 5:
The reviewer observed no issues with resources.

Presentation Number: eems047
Presentation Title: An Estimation of Energy Impacts of Various Policies on Personal Travel Model in the San Francisco Bay Area
Principal Investigator: Tom Wenzel (Lawrence Berkeley National Laboratory)

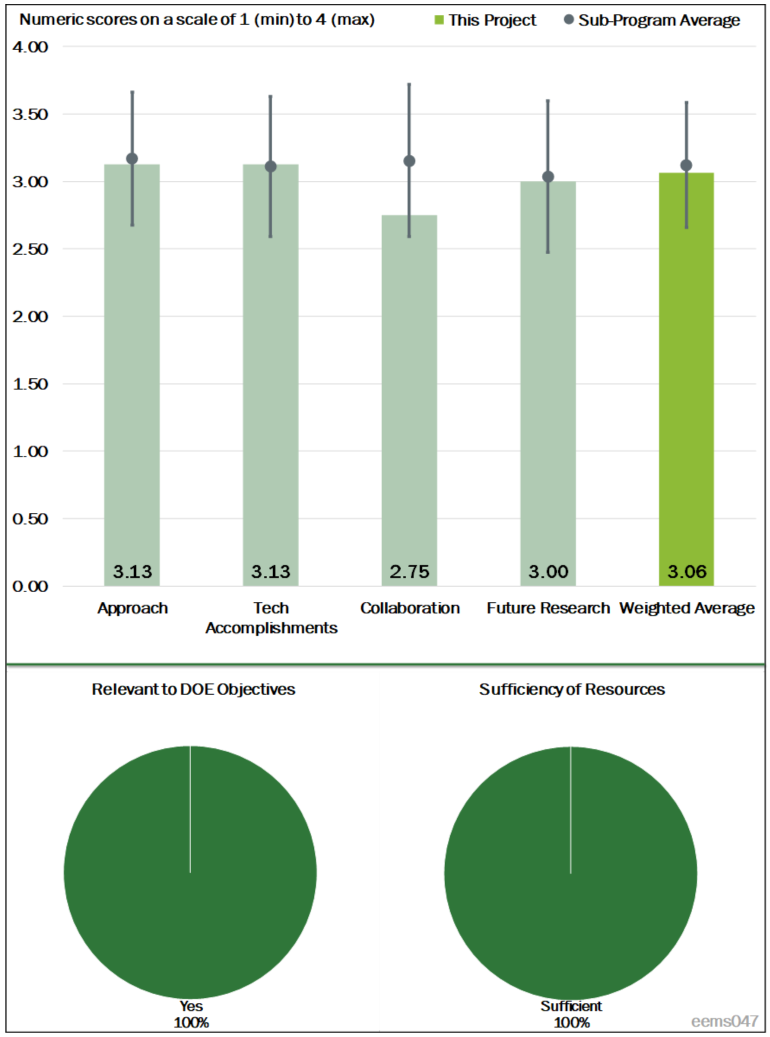

Figure 3-33 - Presentation Number: eems047 Presentation Title: An Estimation of Energy Impacts of Various Policies on Personal Travel Model in the San Francisco Bay Area Principal Investigator: Tom Wenzel (Lawrence Berkeley National Laboratory)

Presenter

Colin Sheppard, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the approach is sound, utilizing and enhancing the BEAM model to tease out energy implications to modal shifts involving transit and TNCs as alternatives.

Reviewer 2:

The reviewer noted that pricing trade-off decisions are important dynamics that EEMS should include in its analysis of mobility energy productivity. The reviewer liked that this project is using real-world questionnaire data to inform its modeling of modal selection decision making. The project is estimating total energy consumption and several modal selection scenarios.

Reviewer 3:

The reviewer detailed that this project answers the critical question of how upcoming mode shifts in passenger transport particularly with regards to TNCs will change energy consumption at the city level. Given the lack of available TNC data, the reviewer thought the approach adopted here is sound and replicable for other cities. The reviewer said the project could be improved by potentially providing modeled analyses for a few more cities and some guidance on next steps to obtaining valuable TNC data that will better help understand their impacts.

Reviewer 4:

The reviewer did not see how the stated barriers were addressed in this work.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer noted that among the notable accomplishments, there is a preliminary validation of the BEAM model with actual observations, which is very valuable. Also, the results around price sensitivities (and price in general) are very important to ultimately understanding the impact on energy use. In particular, the reviewer cited understanding the implications of losing transit service and/or understanding what effect TNC surge pricing has is extremely important.

Reviewer 2:
This reviewer appreciates that the project team has carried the preliminary analysis through to evaluate their key quantitative metrics.

Reviewer 3:
The reviewer said it appears that, to date, the model has provided some interesting preliminary results for San Francisco on the trade-off between transit and TNCs, as well as some of the impacts of key determinants of transit and TNC use.

Reviewer 4:
The reviewer said that it seemed like some good work was done in this study. But still left this reviewer wanting to see more tangible results. The work is academic and not practical in this reviewer's opinion.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer remarked the presentation provided information on specific collaborative contributions that are being made by project partners Stanford and Conveyal.

Reviewer 2:
The reviewer did not have a real sense of the quality of collaboration but it seems like this project's coordination with Conveyal and Stanford University will help to improve the model being developed to estimate energy impacts

Reviewer 3:
The reviewer said it does seem like broader collaboration with consultation with other cities or researchers within the national laboratories or other government agencies would further enhance the value of this research.

Reviewer 4:
The reviewer observed no information on collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that basically, the future research takes the validation of the model that has mostly been achieved, and pivots to examining the impact of long-term system changes on energy use associated with transit system changes. The reviewer found this is logical and of significant value, a reasonable next step.

Reviewer 2:
The reviewer gave this a Satisfactory as it is hard to get all of this information in 15-20 minutes.

Reviewer 3:
It is difficult for this reviewer to get excited about the future work focus on transit systems. This project would get a higher score if the project's focus was on the CAVs.

Reviewer 4:
The reviewer said that this project has identified key milestones for 2018 and 2019 but does not really identify any alternative pathways in the event that specific research questions cannot be answered.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented this work is highly relevant to DOE's goals as it goes to the heart of understanding TNC interaction with traditional transit, and how these interactions affect energy consumption.

Reviewer 2:
The reviewer remarked this work addresses energy consumption as a function of modal choices. This analysis is directly relevant to developing information on energy consumption impacts of new mobility modes.

Reviewer 3:
The reviewer commented this project seems to line up well with EEMS goals as a program to support research on automated, connected, electric, and/or shared vehicles.

Reviewer 4:
The reviewer thought it was on target to the objectives, but the investigator seemed not to have a practical understanding of the substitution of TNCs for mass transit and other modes. The reviewer reiterated the project is academic and not practical.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented the project is making adequate progress to meet its milestones using a limited budget.

Reviewer 2:
The reviewer said that resources seem sufficient for developing a model and following up on 2018 and 2019 milestones.

Reviewer 3:
The reviewer remarked the team has accomplished a significant amount for the resources provided. The reviewer was unclear how much more the team could produce for more funding, but the reviewer also would not recommend reducing funding either.

Reviewer 4:
The reviewer said that resources should be sufficient but cannot be sure.

Presentation Number: eems048
Presentation Title: An Analysis of the Spatial Distribution and Impacts of One-Way Car-Sharing Programs on Transit Ridership and Energy Use
Principal Investigator: Susan Shaheen (Lawrence Berkeley National Laboratory)

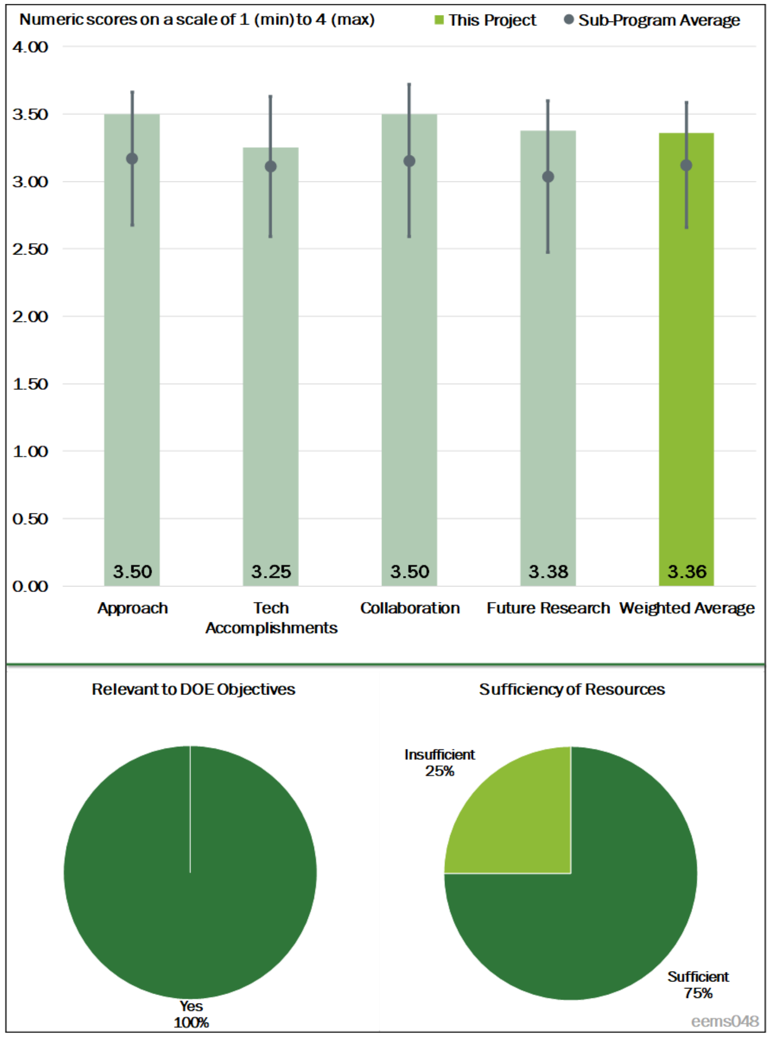

Figure 3-34 - Presentation Number: eems048 Presentation Title: An Analysis of the Spatial Distribution and Impacts of One-Way Car-Sharing Programs on Transit Ridership and Energy Use Principal Investigator: Susan Shaheen (Lawrence Berkeley National Laboratory)

Presenter

Tom Wenzel, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer detailed that the focus of this project is to conduct early-stage R&D at the traveler level to better understand behavioral patterns of drivers, and barriers to increased mobility energy productivity of future integrated mobility systems. Specifically, it is to understand the energy implications of shifts in personal travel, including public transit, from emerging transportation modes such as one-way carsharing. This project will assess the relationships between transit accessibility, urban form, and the impacts from one-way car sharing. These relationships will be applied to other cities and agent-based model simulations. The reviewer noted how the project recognizes there is a limited understanding of the impacts of carsharing and transportation network companies (TNCs such as Uber and Lyft) on energy consumption and their relationship with transit.

The reviewer noted a strong element of this project is that the approach leverages and builds upon an existing survey of users on VMT and mode shift impact to understand spatial factors of survey responses at a very low cost to DOE. This unique existing data set (from car2go and previously funded by the Federal Highway Administration [FHWA], city of Seattle, and the San Diego Association of Governments) contains user survey responses linked to their trip O-Ds. This existing survey covered five cities (Calgary, San Diego, Seattle, Vancouver, and Washington DC), with the car2go program in San Diego having a unique all-EV fleet, which is the future model for automated TNC services. The reviewer noted that Slide 7 presents a number of key research questions which are very salient and informative, and provide a philosophical foundation for the project moving forward.

The reviewer found that this project is very sharply focused upon the spatial distribution and impacts of one-way carsharing and findings will be used to inform the regional modelling efforts under BEAM for San Francisco. A solid set of four logical and progressive milestones are provided and explained, although go/no-go milestones are missing, which probably is not an issue given the limited project scope and funding. The reviewer found that the project is well-designed, surely feasible, and, in short, obtains a lot of mileage and usefulness out of limited funding.

Reviewer 2:

The reviewer said good data sources from rideshare services, and the project is looking at unintended impacts on public transit is high-impact and feasible.

Reviewer 3:

The reviewer observed a very good approach to build on an existing UC-Berkley survey of users (9,500 car2go survey respondents across 5 North American cities) on VMT and mode shift impacts.

Reviewer 4:

The reviewer remarked the survey data from car2go users allows the project to analyze real-world data to gain insights into customer transportation choices that have been affected by having access to the service. One strength of the approach is that it leverages data previously collected for a DOT project. One weakness of the approach is that the data may not accurately interpret cause and effect relationships. The reviewer cited as an example, a contributor to Washington, DC car2go user decrease in public transit may be attributable to the unsafe operations and significant service interruptions of DC metro trains. The reviewer inquired if the switch to car2go service is a sustainable/long-term shift in modal behavior in Washington, DC (or just a temporary preference that will change with improved public transit operations).

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed good data analysis so far, and that a geo-analysis of positive and negative public transit impacts is impressive.

Reviewer 2:

The reviewer noted that INL developed a database of socio-economic characteristics and public transit information in five cities, and LBNL began visualization analysis of survey respondents in the Washington, DC metro area.

Reviewer 3:

The reviewer remarked the project’s geo-coded map products are useful in communicating the spatial distribution data collected on select metro areas. The project results included some relevant data on the energy impacts of the car2go service.

Reviewer 4:

The reviewer remarked the technical accomplishments and progress toward overall project objectives are reasonable and on schedule. As mentioned, the project builds heavily off the previous survey results from car2go.

The reviewer summarized that INL has completed development of a database of socio-economic characteristics and public transit information from the five cities. This database contains a number of elements including population, households, employment by type; land area densities; vehicle ownership and worker by income; trip production and attractions; and road network density, proximity to public transit, frequency of transit, and job accessibility. The reviewer noted that the project identified transit station and bus stop locations, and transit routes, schedules, and frequencies with detailed data for the Washington, DC metro area.

The project conducted spatial mapping analyses for some of these parameters. The reviewer noted that the team provided this information to LBNL, which has geocoded survey respondents to ZIP codes and begun visualization analysis of survey respondents.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the primary team members are LBNL and INL. For a small task with a limited scope, there are good collaborations with car2go, FHWA, the San Diego Association of Governments, and the City of Seattle to leverage existing survey information and practical experience.

Reviewer 2:

The reviewer commented looks like good coordination between LBNL, INL, and rideshare partners providing data.

Reviewer 3:

The reviewer noted collaboration between LBNL and INL within the SMART Mobility Lab consortium, as well as leveraging information from FHWA car2go project participants.

Reviewer 4:

The reviewer remarked there is evidence that LBNL is making use of INL's and car2go's data.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that plans for the remainder of the project look like they will produce good results, particularly applying results to San Francisco.

Reviewer 2:

The reviewer pointed out that developing statistical models to estimate relationships and using the models to estimate energy and other impacts of one-way carsharing will likely make significant contributions to EEMS research areas.

Reviewer 3:

The reviewer observed the future work is clearly and logically laid out with each element having a specific deliverable date. The future work includes finishing the visualization analysis of the relationship between the spatial distribution of car2go impacts and characteristics in each city; developing statistical models to estimate relationships; using the models to estimate energy and other impacts of one-way carsharing in a new city (DOT Smart City Finalist); summarizing results in a report or journal article; and ultimately using the findings as inputs to the LBNL BEAM model to simulate one-way carsharing in the San Francisco Bay Area.

The reviewer remarked as indicated, the findings from the project can be applied to other types of shared mobility modes in other environments, as well as provide a better understanding of how systems perform in specific environments to support more efficient decisions on designing public transit. The project identified two salient questions to be answered, which this reviewer quoted from the Summary. The first question quoted by this reviewer is, "Under what circumstances do one-way carsharing and other shared mobility systems support or undermine public transit?" The second question quoted is, "What metrics define when mobility systems are most efficient in specific environments?" The reviewer concluded that future work follows a logical progression to obtain the most out of its findings.

Reviewer 4:

The reviewer remarked that the planned work is a logical pursuit of the project objectives. The reviewer pointed out it may be useful for the statistical modeling to include correlation analysis of the variables.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that this work is clearly relevant to increasing the relationships between new mobility choices and energy use.

Reviewer 2:

The reviewer pointed out that understanding rideshare services are essential to understanding future transit. Rideshare is already impacting transit in unforeseen and currently un-comprehended ways.

Reviewer 3:

The reviewer said yes, this project supports overall DOE objectives. Specifically, it will help better understand the drivers of human behavior, which influence the viability of increased mobility energy productivity and the energy implications from shifts in personal travel, including public transit, to emerging transportation modes such as one-way carsharing.

Reviewer 4:

The reviewer noted that this project focuses on early-stage R&D at the traveler level for a better understanding of behavioral drivers and barriers to increased mobility energy productivity of future integrated mobility systems. The reviewer found that early results seem mixed but there is potential for reduced use of petroleum.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked, based on the limited results presented, the car2go database has only been partially exploited. This project has a modest budget, and additional funds may be useful for increasing the results from this project.

Reviewer 2:

The reviewer found that the resources are tight but sufficient to achieve the stated project objectives and milestones in the allotted timeframe.

Reviewer 3:

The reviewer remarked great use of DOE funds (only $375,000) to leverage more than a $1 million previous investment by FHWA and extract EEMS-relevant learnings from a significant existing survey dataset.

Reviewer 4:

The reviewer said the resources seem in line with the work performed.

Presentation Number: eems049
Presentation Title: Vehicle Modeling and Data Analysis: Transportation Secure Data Center (TSDC), FleetDNA and FASTSim
Principal Investigator: Jeff Gonder (National Renewable Energy Laboratory)

Presenter

Jeff Gonder, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

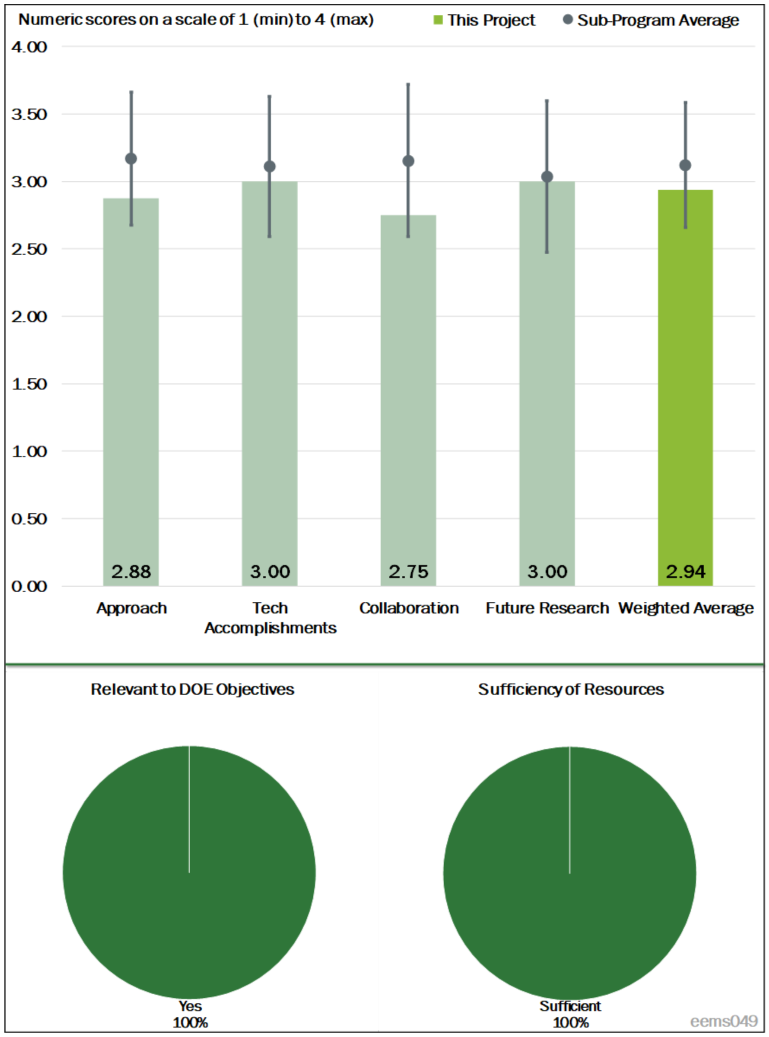

Figure 3-35 - Presentation Number: eems049 Presentation Title: Vehicle Modeling and Data Analysis: Transportation Secure Data Center (TSDC), FleetDNA and FASTSim Principal Investigator: Jeff Gonder (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said good outline of the objectives and key metrics on how to achieve them.

Reviewer 2:

The reviewer said the project seemed to address the availability of data for other studies.

Reviewer 3:

The reviewer found that the approach is very good and relevant.

Reviewer 4:

The reviewer said that the approach is appropriate for this stage of the project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that accomplishments are appropriate for this stage of the project.

Reviewer 2:

The reviewer pointed out that data sampling and analysis are critical, along with having a wide sample size that reflects different drive environments and regions.

Reviewer 3:

The reviewer remarked great data and information so far, and need to take this to the next level.

Reviewer 4:
The reviewer said it is very hard to tell in the time given how well this and other projects are truly progressing.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said that the work plan among the collaborators is effective.

Reviewer 2:
The reviewer said good collaboration and team members, and the project should get more commercial input.

Reviewer 3:
The reviewer remarked not a lot of information on collaboration during the discussion.

Reviewer 4:
The reviewer pointed out there are areas in this project that could provide additional value to other EEMS projects. This collaboration has improved from the past, but has more potential for improvement in the future.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that proposed future research is appropriate for this stage of the project.

Reviewer 2:
The reviewer remarked future research can produce great tools.

Reviewer 3:
The reviewer noted that it is critical to have a large sample size of data, for different regions and drive scenarios.

Reviewer 4:
The reviewer remarked the project ends soon, so not much else to report on.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The project helps to get a lot of data available to others, according to this reviewer.

Reviewer 2:
The reviewer said that the outcome is a factor in understanding the drive behavior and will help with choosing the right technology for future mobility.

Reviewer 3:
The reviewer remarked will save fuel and reduce congestion.

Reviewer 4:
The reviewer said this is appropriate for this stage of the project.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said should have more funding to produce powerful tools

Reviewer 2:
The reviewer said that resources are appropriate for this stage of the project.

Reviewer 3:
The reviewer observed no issues with resources.

Reviewer 4:
The reviewer said not much left to do, so should be able to complete in the time given.

Presentation Number: eems051
Presentation Title: SMART Mobility Modeling for Typical Mid-Size City
Principal Investigator: Andrew Duvall (National Renewable Energy Laboratory)

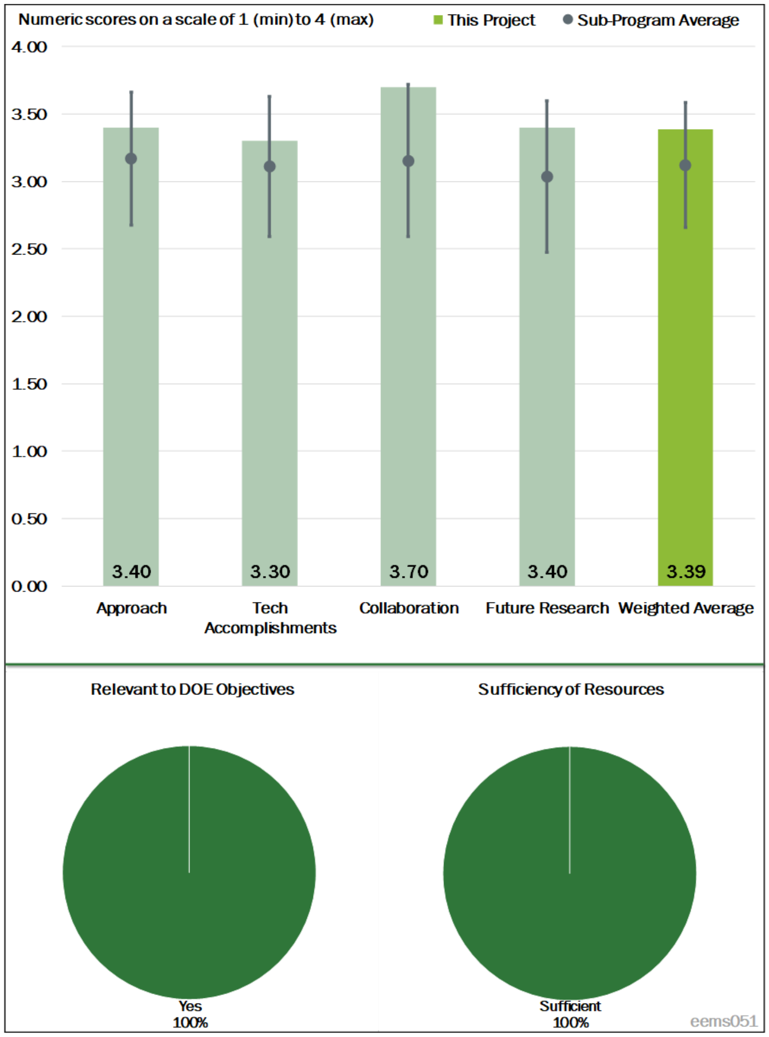

Figure 3-36 - Presentation Number: eems051 Presentation Title: SMART Mobility Modeling for Typical Mid-Size City Principal Investigator: Andrew Duvall (National Renewable Energy Laboratory)

Presenter
Andrew Duvall, National Renewable Energy Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer remarked the approach appears sound, and it is a good way to collect specific data for these predictive models by working with specific cities and to ensure replicability.

Reviewer 2:
The reviewer observed a good approach to accomplishing the important task of incorporating tech-enabled mobility strategies into existing transport planning and analysis processes. The presentation indicates that approach is adaptable to existing modeling platforms, and that many metropolitan planning organizations or cities should have the capacity to use the resulting methods/tools.

Reviewer 3:
The reviewer described the key objective of this project is to extend existing transportation data and models to include emerging smart transportation options to better assess affordability, efficiency, safety, and mobility accessibility. This includes mobility as a service, ubiquitous communications, and automation. An additional focus is to develop recommendations for extension of current models to include emerging travel technologies and practices.

The reviewer identified as barriers transportation models do not integrate smart technologies, and that foundational modeling data sources are not contemporary and insufficiently flexible to maintain accuracy. The reviewer said that the project's approach is to work directly with city research entities (Texas A&M Transportation Institute [TTI] and Metropia) which are knowledgeable of the Austin, Texas, and Columbus, Ohio travel demand models and associated data. This will establish a good understanding of the modeling capabilities of these two cites. Subsequently, according to the reviewer the approach looks to extend the existing models incrementally to include smart mobility technologies and estimate mobility and energy impacts of smart technologies within the existing/established modeling framework as a case study for other cities. Finally, integrate findings from the ARPA-E Traveler Response Architecture using Novel Signaling for Network Efficiency in Transportation (TRANSNET) project to augment modeling capabilities.

The reviewer found this approach is sound and feasible especially because it emphasizes close working relationships with local entities with extensive knowledge of the modeling capabilities of these cities and focuses upon augmenting existing models as opposed to creating new models which can be very expensive. Identifying and developing tools (potentially open source) are emphasized to minimize cost and maximize potential applicability to other cities' modelling platforms. Additionally, according to the reviewer the project builds upon results of the ARPE-E TRANSNET project including use of the Metropia mobility app which leverages incentives, convenience to shift behavior, and learns user preferences.

Reviewer 4:

The reviewer commented that the research focuses on reviewing existing transportation models and their shortcomings for incorporating smart mobility technologies for assessing energy and mobility impacts. Researchers are looking at incremental ways of improving existing models rather than a clean sheet of paper approach that would be ultimately more cost-effective and faster to implement. The reviewer noted that the researchers are working with two of the more progressive Smart Cities in the country, Columbus and Austin, in using their existing transportation model platforms as a means to evaluate existing models and identify ways to improve for new technologies. The research is also leveraging off ARPA-E TRANSNET project results using relevant tool and models from these efforts.

Reviewer 5:

The reviewer said that although the objectives of the project are interesting and relevant, the proposed approach does not provide a well-thought and detailed-oriented plan towards achieving these objectives. To the reviewer, it seemed that there is a significant overlap with previous work funded by ARPA-E.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that accomplishments appear to be ahead of schedule.

Reviewer 2:

The reviewer remarked although the project started relatively recently, the team has made significant progress.

Reviewer 3:

The reviewer commented the project to date has achieved a significant amount of work, including scoping conditions in Austin and Columbus as well as delivering recommendations for the creation of smart transportation systems.

Reviewer 4:

The reviewer reported that as of the AMR conference, the researcher indicated the project is 25% complete. For a 2-year project initiated in October 2017, the project pace seems reasonable. FY 2018 accomplishments include assessments of existing transportation models for Austin and Columbus and their respective capacities for incorporating smart technologies. The reviewer noted that a the project developed a recommendations report for Austin and Columbus with the key finding that its existing model should be augmented and expanded for incorporating new technologies, not replaced. The reviewer said that model development in these cities will support smart technology application in other cities using different models, so model flexibility in incorporating new technologies will be important and open source tools may be advantageous.

Reviewer 5:

The reviewer noted several technical accomplishments. The reviewer detailed that NREL has developed methods to estimate the energy impact of travel options presented through the Metropia app. The project tailors energy units presented to users to individual preferences, and estimated system-scale energy impacts from aggregated user data.

The reviewer noted the assessment and modeling report for Austin, Texas is being developed and has identified innovations in the Austin Smart Mobility Roadmap, including a two-way open data portal, framework for interactive data flow, and connected traveler initiative. The Austin Smart Mobility Roadmap details plans to foster shared electric and autonomous vehicle technologies and identifies the need for advancement and augmentation of existing models. The reviewer noted that a key message identified is that replacement of current models or frameworks is not recommended due to the high level of effort and cost for a completely new model. Augmenting existing models is viable and cost effective.

The assessment and modeling report for Columbus, Ohio is being developed and has identified that the MORPC and Ohio Department of Transportation (ODOT) have developed an activity-based model (ABM) for forecasting and analysis and in 2017 integrated the DynusT model for dynamic traffic assignment. The reviewer noted that MORPC and ODOT are working towards transitioning to an agent-based modeling and simulation (ABMS) framework, capable of incorporating smart mobility technologies. The integrated framework provides the initial step in transitioning to an ABMS framework and could serve as an intermediate assessment platform prototype for other cities exploring new technologies and mobility options. The reviewer noted that the key message is that it is essential for Columbus to develop robust, updatable, next-generation modeling capabilities to reflect emerging transportation technologies.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted strong collaboration with a varied team.

Reviewer 2:

The reviewer commented that the project has established nice collaborations among the partners with complementary roles.

Reviewer 3:

The reviewer remarked that the partner list is comprehensive and thorough. Each organization is a relevant stakeholder and has identifiable roles and specific contributions to the project.

Reviewer 4:

The reviewer reported that NREL is working closely with TTI and Metropia, relationships which were originally developed through the ARPA-E TRANSNET project. Collaboration and coordination is conducted with other institutions, including the Columbus Partnership, MORPC, Ohio State University, University of Texas Center for Transportation Research, City of Austin, Austin Energy, Pecan Street Development (Austin), and Texas DOT. Overall, a broad series of collaborations at many levels for a modestly sized task.

Reviewer 5:

The remarked that collaboration on this project is extensive, and noted that the research team is working with TTI (Austin-related Smart City model support) and Metropia (DynusT modeling support for Columbus). NREL, TTI, and Metropia have worked together previously through the ARPA-E TRANSNET program. The reviewer pointed out that the researcher also claims collaborative efforts with organizations involved in Columbus (The Columbus Partnership, Mid-Ohio Regional Planning Commission, Ohio State University) and Austin (University of Texas, City of Austin, Austin Energy, Pecan Street Development, Texas DOT) Smart City development efforts.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer found that future research plan makes sense. The team identified possible data sources for emerging transportation options, though availability is uncertain.

Reviewer 2:

The reviewer said that the team has in place a solid plan to address the remaining challenges and barriers in FY 2018.

Reviewer 3:

The reviewer remarked that the project recognizes the impact of data availability on planning for smart systems and has wisely focused future work on this as well as understanding how to bulk up future models with additional information, scenarios, and data.

Reviewer 4:

The reviewer said that the future work is in-line with what has already been accomplished and the objectives of the research. Researchers propose to refine the recommendations for Columbus and Austin and extrapolate results for application to other mid-size cities, identify new data sources, and modeling methods for mobility-as-a-service, AVs, and for extension to additional transportation models, and estimate energy and mobility impacts using an existing modeling framework as a case study for other cities.

Reviewer 5:

The reviewer remarked that the project has identified current transportation models and characteristics of sample cities, and developed recommendations. The next step is to develop strategies to achieve recommendations for extension of models. The reviewer reported that challenges therein include identifying sources for emerging transportation and enabling production and integration of tools and frameworks to extend existing models to other cities and regions.

For the remainder of FY 2018, the reviewer detailed that the project will refine report recommendations and develop and implement an approach for employer-provided mobility, AMD special generator, and/or TNC use. For FY 2019, the project will bring in new data and modelling methods for MaaS, AVs, and other emerging mobility choices. The reviewer said that existing travel demand models will be extended and be transferrable to additional cities and regions. Additionally, the project will estimate automated, connected, electric, and/or shared (ACES) mobility and energy impacts within an existing/established modeling framework as a case study for other cities.

The reviewer said that the proposed future work is logical and heavily leverages existing resources and collaborations with other organizations. If successful, the resulting findings and model augmentation strategies would be very useful to other cities contemplating aggressive moves towards smart mobility. The reviewer said that it would have been helpful if some additional technical insight was provided as to how existing models can augmented and transferred to other cities. Additionally, there is no discussion of alternate development pathways should envisioned model augmentation schemes prove inflexible and largely-non transferrable.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer commented yes, this project supports the DOE EEMS program through support for development of new tools and models for assessing energy and mobility impacts of smart technologies.

Reviewer 2:
The reviewer said the project supports DOE objective of reducing petroleum consumption and the EEMS objective of decoupling mobility from energy use.

Reviewer 3:
The reviewer said yes, and explained that the project addresses energy, infrastructure, and investment impacts of incorporating smart mobility into transportation systems.

Reviewer 4:
The reviewer said the project will extend existing transportation data and models to access efficiency, safety, and accessibility of mobility. So, it is relevant and addresses DOE's objectives in this domain.

Reviewer 5:
The reviewer commented the development of replicable methods to augment and transfer transportation modelling capabilities (including new smart mobility technologies) to other cities would be instrumental to overcoming barriers. These models would be very useful for transportation planning and would help identify cogent arguments for key government entities and private sector companies to pursue smart mobility.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented the resources identified ($350,000) are reasonable and appropriate to achieve the project objectives and milestones.

Reviewer 2:
The reviewer remarked that the partners have enough resources to meet the milestones.

Reviewer 3:
The reviewer commented the budget is appropriate for the activities of the project.

Reviewer 4:
The reviewer remarked it is difficult to assess adequacy of resources without knowing more about ARPA-E TRANSNET project methods.

Reviewer 5:
The reviewer said funding seems somewhat uncertain for this project. If all the money comes through then yes, it will be sufficient.

Presentation Number: eems052
Presentation Title: Resiliency Analysis for Automated Mobility Systems
Principal Investigator: Joanne Wendelberger (Los Alamos National Laboratory)

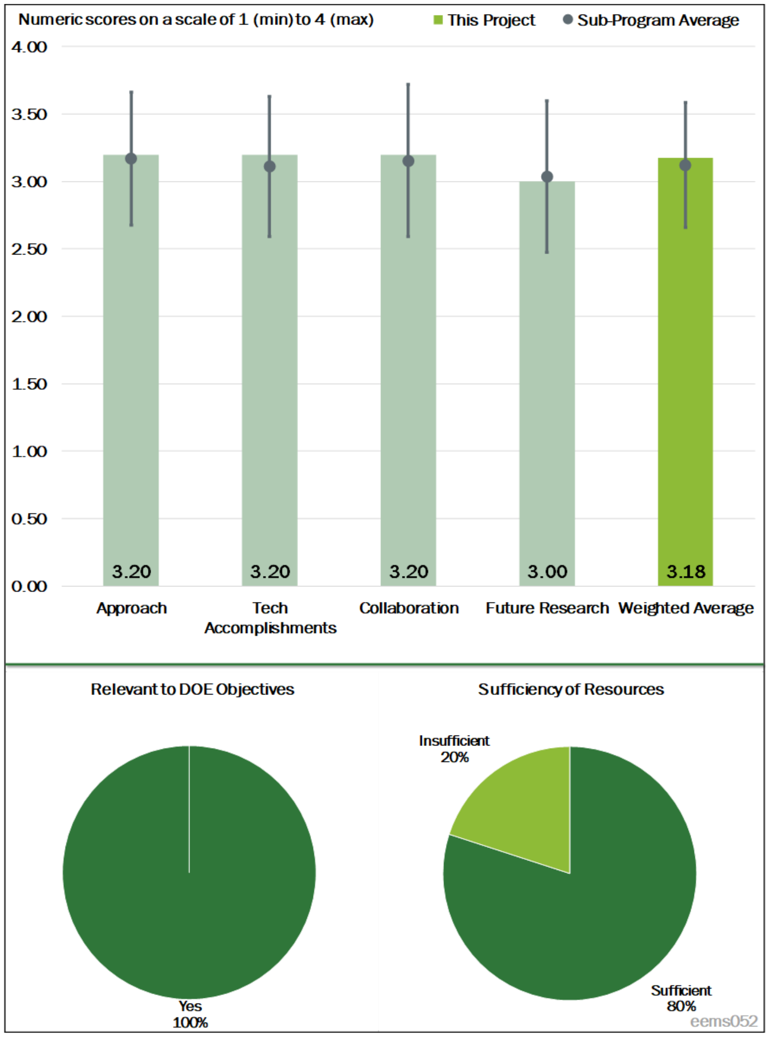

Figure 3-37 - Presentation Number: eems052 Presentation Title: Resiliency Analysis for Automated Mobility Systems Principal Investigator: Joanne Wendelberger (Los Alamos National Laboratory)

Presenter

Joanne Wendelberger, Los Alamos National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer rated this as good, and remarked this is a new project with a grand total budget of $140,000, which means that the authors are just starting to think about this. Although, if the authors could put this in equivalent man-hours or engineering heads, this would be more straight-forward.

Reviewer 2:

The reviewer detailed that the overall objective of this task is to develop a statistical approach to understanding system resilience strategies for smart city transportation technologies (EVs, CAVs, and AMDs) to assist with planning and mitigation actions during extreme conditions (special events, natural disasters, emergency situations, etc.). The focus is to provide quantitative approaches for addressing resilience including building a quantitative framework and anticipating how systems will respond under stress and planning accordingly. The reviewer said that the approach is intended to be broadly applicable, including potential applications in transit systems, on-demand ride services, and charging station infrastructure.

The reviewer noted the team presented some high-level barriers, including understanding how systems will respond to abnormal conditions; quantifying resilience; and developing systems that will be robust and able to recover from extreme conditions. The reviewer commented that the team provided a solid level of background material, including information on: the Statistical Planning for Resilience in Next Generation Systems (SPRINGS) conceptual model for resiliency including a block diagram, an example using a trolley simulation, quantifying resilience, and resilience planning. The reviewer found especially appealing the slide which provides a framework and process for quantifying resilience.

The reviewer said that the proposed approach is through SPRINGS. This approach uses statistical methods to characterize distributional behavior of systems under normal, stressed, and extreme conditions. The approach models the impact of disruptions to normal operating conditions and resilience of system response as abnormal conditions subside. The reviewer detailed that next, interventions are introduced and studied to characterize the impact of abnormal conditions on system behavior and key drivers. Subsequently, the use of resiliency modelling is demonstrated to proactively anticipate and address overcapacity and/or loss of infrastructure for EV/AMD systems.

The reviewer found that this approach will characterize and develop an understanding of how systems will respond to stressed and extreme conditions in the presence of new technologies and other distributions; quantify resilience including proposing metrics of different aspects of system resilience and incorporating data from multiple sources for evaluation; and strive to develop strategies to enable identification and implementation of robust systems.

The reviewer assessed that this is an interesting, early stage, exploratory project for which there are no clear exemplars. It seeks to explore areas (resiliency) largely untouched within the transportation space. The reviewer found that it appears to be well-designed and potentially feasible. The team has provided a significant amount of detail indicating it has been well-conceptualized with a clear focus and direction.

Reviewer 3:

The reviewer remarked the research project focuses on developing a better understanding and quantification of how automated mobility systems respond to extreme conditions as well as the development of statistical tools to assist in designing and planning these systems that can be used by municipalities and other stakeholders. For FY 2018, the reviewer said the approach seems reasonable in developing an initial resilience framework and potential data sources, implementing and testing statistical methodologies using simulated data, developing case studies to evaluate the framework, and then expanding the framework by adding more complex scenarios. The reviewer remarked that using the SPRINGS approach seems appropriate as applied to AMS.

Reviewer 4:

The reviewer found that the technical barriers are clearly stated. However, the outreach to obtain data to support the modeling and validation activity appears somewhat tentative. The PI has reached out to various data sources, but does not appear to have access to any significant amount of data yet. Secondly, according to the reviewer if this project is to support the DOE EEMS goal, then it should specifically investigate how the methods developed in this project allow us to evaluate the resilience strategies for smart city technologies as opposed to the status quo. The baseline would have to be the strategies that exist now according to this reviewer, who questioned “dumb city strategies.” The reviewer said that there does not appear to be any focus on the baseline.

Reviewer 5:

The reviewer remarked that this looks like an analytically sound project, and injecting rigor into resilience evaluation is valuable. However, there is no discussion about the relationship between the project approach and cities’ ongoing efforts to increase resilience, so the reviewer was unclear how useful the project will be.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted the researcher stated that the project is about 50% complete as of the AMR conference. Given the October 2017 start-up and 1-year (as currently funded) timeframe, this pace of progress seems appropriate. The reviewer noted that technical accomplishments cited included development of simplified conceptual model for assessing disruption and resiliency, a simplified closed loop trolley simulation for initial application, evaluation of system variables on operation, development of resilience metrics, identification of the SPRINGS approach for modeling extreme behavior, and employment of socio-technological analysis to identify resiliency planning strategies and their strengths/weaknesses. The reviewer assessed that through FY 2018 Quarter 2, the researcher has developed a technical report, a conference poster, and two presentations.

Reviewer 2:

The reviewer remarked that the objectives for the October 2017-April 2018 timeframe included developing a conceptual model, identifying statistical concepts and methods, and beginning to explore methods using simulated data. Four milestones (one for each quarter in FY 2018) are laid out and sufficiently detailed.

The reviewer assessed that the project is on track and has achieved an impressive level of technical accomplishments in a short period of time. This includes development of a conceptual model to examine the processes of disruption and recovery; a simple closed loop trolley simulation was developed as a precursor to more complex systems; simulation results were used to provide information on the impact of changes to system variables; resilience metrics were proposed; the SPRINGs approach was proposed for modelling extreme behavior; and socio-technological analysis identified key concepts and resiliency planning strategies along with strengths and weaknesses. The team documented all results via a technical report, a conference poster, and two presentations to meet FY 2018 Quarter1 and FY 2018 Quarter 2 deliverables.

Reviewer 3:

The reviewer remarked significant progress appears to have been made in the project. The reviewer expressed some reservations about some aspects of the project. The reviewer is not quite sure whether special events qualify as extreme. The purpose of this project, it seems, is to plan for extreme events that occur very infrequently. Special events are typically planned events, and are not infrequent. The reviewer remarked that the focus should perhaps be to develop models and strategies to address events that are beyond what is normally observed. Sporting events, conferences, and trade shows are normal, and one would hope that the city planners have already accounted for these type of events. The reviewer acknowledged that of course, information from such events may provide valuable validation data for the model.

Reviewer 4:

The reviewer said that the project appears to be on schedule, though it is not entirely clear from the presentation.

Reviewer 5:

The reviewer said that there really have not been technical accomplishments. This is more of “setting up” a project to begin. Although, the reviewer wondered why the authors pick the Kansas City Trolley, and why not look at this as to what happened to infrastructure, let alone Tesla EVs during Hurricane Irma.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that there is active collaboration and coordination across the team.

Reviewer 2:

The reviewer noted the project is led by Los Alamos National Laboratory (LANL) and incorporates input and subject matter expertise from INL. Collaboration and coordination exist with other entities including members of the Urban Science Pillar of SMART Mobility, and possibly NREL with regards to data from TNCs and design and analysis of computer experiments for investigating resilience. The reviewer noted the project has also been in contact with Smart City finalist Kansas City planners to explore data sources associated with the Kansas City Streetcar and charging infrastructure, and has had discussions with the University of Michigan regarding modeling of campus bus data, and the National Science Foundation (NSF) regarding their resilience effort. The reviewer remarked overall, a solid list of collaborations and engagements for the early stages of a small, exploratory task.

Reviewer 3:

The reviewer said that collaborative efforts for the project have been good. The researcher is working with SMART Mobility Consortium member, INL, utilizing its technical and technological subject matter expertise in AMS and technologies. The researcher has also collaborated with NREL regarding TNC data sources and computer analytical designs for investigating resiliency. The reviewer pointed out efforts in data source identification have also included discussions with Smarty City Kansas City organizations and the University of Michigan. According to the reviewer, the researcher also cited discussions with NSF regarding its resilience efforts, but did not provide specific details about those discussions and how they relate to the project.

Reviewer 4:
The reviewer noted that there appears to be collaboration with the INL team, but much of the other collaboration appears to be planned, and has not yet borne fruit.

Reviewer 5:
The reviewer remarked that with LANL and INL, this is a great start. But, the reviewer asked the authors to explain why NREL and why Kansas City. The reviewer asked why Kansas City's trolley was picked, and why not pick areas where there are significant weather systems, or significant Federal Emergency Management Agency issues. The reviewer asked what the authors are concerned about in Kansas City—such as tornados.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that given the somewhat limited funding, the proposed research is well-planned out. Perhaps applying the model on an actual example, using a mesoscale simulation tool such as BEAM or POLARIS), where a major disruption in the supporting infrastructure can easily be introduced, may be a good way to showcase the overall approach. The reviewer pointed out this would also involve more collaboration with other national laboratories, which is a good thing.

Reviewer 2:
The reviewer said the project has identified remaining challenges and barriers including: the technical challenge of modelling extreme behavior that has only infrequently or never been modelled before; the fact that validation of the resilience approach will necessitate access to data which may require significant effort; and data collected for other purposes may not be adequate for modelling resilience. The reviewer commented the project presents a logical, progressive, and detailed approach for proposed future research. This includes: building on the preliminary framework to implement the SPRINGS resiliency approach; continuing efforts to obtain access to mobility system data; examining work by other researchers (transportation and emergency) to gain further insights; actively probing systems and examining flows as different interventions are introduced to experiment with different strategies; developing resiliency strategies; and exploring dynamic visualization methods to enhance the resiliency modeling process and communication of models and results. The reviewer did not notify any notable omissions. The reviewer remarked that the project, however, does not really discuss nor identify other potential solution pathways should the SPRINGS approach provide infeasible whether technically or through lack of sufficiently appropriate data for validation.

Reviewer 3:
The reviewer commented that the remaining FY 2018 activities planned under the project are reasonable and build upon earlier work. These activities include the development of case studies using the initial framework followed by the expansion of the framework to include more complex scenarios through review of research on transit systems, autonomous vehicles, and emergency and natural disaster situations. The reviewer pointed out the researcher recognizes that data may be a limiting factor for this work in terms of identifying sources and its viability for modeling system resilience. The reviewer noted that FY 2019 funding is pending funding approval but would involve further development of the framework and its demonstration on specific mobility systems.

Reviewer 4:

The reviewer pointed out that uncertainty about availability of data is a major challenge to further work. The reviewer also pointed out interaction with cities interested in resilience planning would help to ensure the utility of the project.

Reviewer 5:

The reviewer remarked this is a start and thought there are a lot of places to make significant strides here. This reviewer referenced Irma, where one could see gas stations closing, highways clogged, airports shutting down, and Tesla doing over-the-air (OTA) updates to get longer range.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer commented DOE is investing heavily in EEMS, and while the potential for petroleum displacement and increased access to mobility is very high, it would be of great interest to understand how these new systems and transportation infrastructure respond to extreme events, compared to the systems that are currently in place.

Reviewer 2:

The reviewer said there is a relationship between resilience and DOE's objective of petroleum displacement, but the researcher should spell out this connection in work products and outreach. The reviewer remarked reduced dependence on transport fuels could be identified as a resilience strategy.

Reviewer 3:

The reviewer said in a different way, this project is relevant to DOE objectives. Resilient, smart transportation systems can be integral elements of Smart Cities by providing increased safety and life-savings capabilities in extreme disaster situations, augmenting city functions (e.g., medical services, buildings) during brown-outs or other limited power scenarios, and potentially reducing emissions and increasing the quality of life in urban areas.

Reviewer 4:

The reviewer said that the project is relevant to DOE EEMS programs and objectives in supporting the development of tools and models for assessing AMS. The project supports the development of AMS by providing a statistical tool for assessing system resiliency under extreme conditions.

Reviewer 5:

The reviewer exclaimed absolutely, but said to make this more tangible. The reviewer wondered if this is worry about a truck running into the Kansas City trolley, or about power interruption. The reviewer asked about where the trolley goes, and the number of people that ride the trolley. The reviewer said the authors could have done something similar, such as the train on the east coast running into the wall, and said to make this real.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked for an early-stage exploratory project in an area with relatively little to build upon, the resources are thin but sufficient. The reviewer remarked if the SPRINGS concept pans out, more significant resources will be needed to bring the concept to fruition.

Reviewer 2:

The reviewer said that the budget is small but appropriate at this point given the limited scope of work. However, there is a mention of a possible data shortage, which could relate to budget issues.

Reviewer 3:
The reviewer remarked this project's funding appears appropriate for FY 2018, and FY 2019 funding is pending approval.

Reviewer 4:
The reviewer noted that the funding for this project appears somewhat limited. The reviewer would think that a more extensive simulation of various scenarios, supported by appropriate data, and the acquisition of those data would require more funding than what has been allocated for the completion of this project.

Reviewer 5:
The reviewer commented it is a start.

Presentation Number: eems053
Presentation Title: Infrastructure Spatial Sensing at Intersections
Principal Investigator: Stan Young (National Renewable Energy Laboratory)

Presenter

Stan Young, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

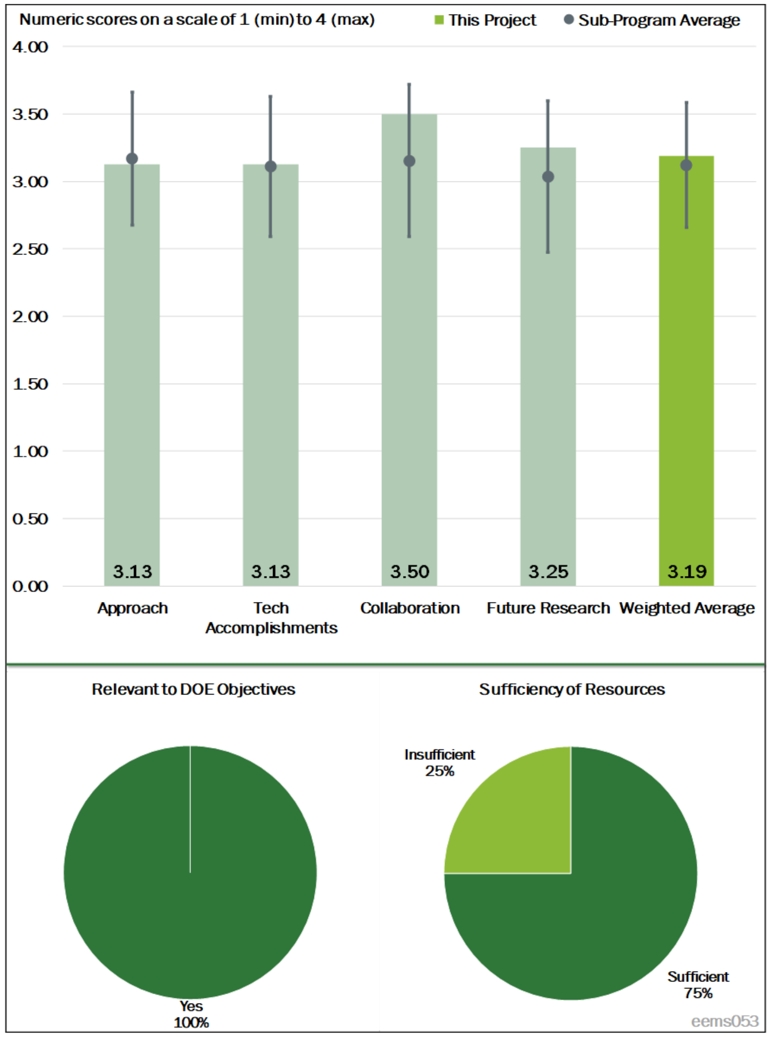

Figure 3-38 - Presentation Number: eems053 Presentation Title: Infrastructure Spatial Sensing at Intersections Principal Investigator: Stan Young (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that this is a good approach as this is a quick look project to review infrastructure sensing technologies such as LIDAR in stationary application like an intersection. This is a very low-cost approach leading up to a go/no-go decision for potential demonstration in FY 2019. The reviewer was unclear if Continental technology is a commercial system or still under development. If commercial, the reviewer asked what the intended use is (likely safety), and what analytics are already part of the system.

Reviewer 2:

The reviewer said that the research focused on better understanding of potential spatial sensing technologies for intersection applications in supporting AMS and reducing energy consumption, especially in light of potential benefits to a broader range of stakeholders (e.g., traffic control, pedestrians, etc.). The scope involves reviewing current spatial sensing technologies and applications to identify research gaps for mobility systems, followed by identifying commercial sensing technology partners for creating and demonstration HPC methods to analyze and communicate spatial information for mobility system applications.

Reviewer 3:

The reviewer detailed that the objective of this project is to explore the mobility/energy impact potential of spatial sensing (such as LIDAR) at critical intersections in the real world. Successful implementation of this project would enable the potential capability to track all objects (conventional vehicles, connected vehicles (CV), AVs, pedestrians, and bikes) for enhancing mobility and energy efficiency.

The reviewer detailed the high-level barriers that the authors have identified, including: understanding the existing space and literature regarding mobility/energy potential of spatial sensing (such as LIDAR) at critical intersections; exploring energy equivalence of improved safety at signalized intersections; and industry is primarily focused on on-vehicle sensing, but on-infrastructure implementation might afford more benefit to a wider set of stakeholders (pedestrian, traffic managers).

The reviewer said that the project approach includes: reviewing state-of-the-art infrastructure sensing technologies and applications, and highlighting gaps and focus areas to enable enhanced mobility energy productivity (MEP), developing memorandums of understanding and non-disclosure agreements with industry partner(s); developing a draft assessment of the energy equivalence of safety at intersections; and establishing high-speed, real-time data links with partners (Continental, University of Nevada, Reno [UNR]) for field data. The team established a go/no-go milestone for FY 2019 to move onto an FY 2019 demonstration. The reviewer found that it would have been beneficial to explain the criteria for successfully achieving the go/no-go milestone and provide a specific target date. The reviewer assessed that overall, the project appears well-designed and feasible and the approach will address the aforementioned technical barriers.

Reviewer 4:
The reviewer said that this is an interesting pilot. The reviewer was still not clear what the application of technology like this would be in the real world and what the goal of a system like this would be.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer noted that a 2-year duration was listed for the very small project (only $50,000) and is 50% complete (likely delays due to budget uncertainty). The reviewer detailed how ANL has developed a proof of concept exploratory portable awareness system, UNR has installed LIDAR sensors at a campus intersection, and the team is engaging Continental for data sharing from Columbus, Ohio demonstration. In addition, energy equivalence of safety improvements/crash avoidance has been quantified.

Reviewer 2:
The researcher stated that the project is about 50% complete as of the AMR conference. This progress appears to be somewhat ahead of schedule for a 2-year project with an October 2017 start-up. Technical accomplishments in FY 2018 have included reviewing technologies and identifying technology partners (ANL, UNR, and Continental), and assessing energy equivalence metrics for safety improvements and crash avoidance for intersections.

Reviewer 3:
The reviewer noted that the project is on schedule, and for a small effort a strong list of technical accomplishments has been achieved in a short time. To date, identified milestones have been achieved. Specific technical accomplishments include: ANL’s proof of concept exploratory portable awareness and data collection system; UNR has installed and networked LIDAR sensors at intersections near campus with full data streams to traffic research center starting in March 2018 (also exploring data transmission to NREL in real-time);a controlled demonstration of Continental’s infrastructure spatial sensing system was conducted in Brimley, Michigan in 2017 with a demo planned for Columbus, Ohio in 2019; and the energy equivalence of safety improvements/crash avoidance has been identified and highlighted.

Reviewer 4:
The reviewer said that the project seems to be on track for a 2019 completion.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that collaboration partners include UNR, University of Maryland (UMD), and Continental. The relationship with Continental to get access to their field deployment data is critical for potential follow on work.

Reviewer 2:

The reviewer commented that the project has thus far exhibited outstanding collaboration and coordination. The prime participants are ANL and NREL with close coordination with UNR, Continental AG, and UMD. Each partner brings different capabilities and expertise. UNR has expertise in intersection spatial sensing techniques including LIDAR technologies. Continental AG is a leading German OEM with expertise in intersection sensing data sharing and abstraction, and UMD is skilled at assessing the energy equivalence of accident research. The reviewer assessed that this appears to be an excellent balance of team members for the project at hand.

Reviewer 3:

The reviewer remarked the project appears to have effective collaboration with other organizations. The team is working with SMART Mobility Consortium member, ANL, as a technology partner (proof of concept portable awareness system and data collection). The project is also working with partners UNR (LIDAR sensor demonstration), Continental (intersection spatial sensing data sharing), and UMD (energy equivalence research).

Reviewer 4:

The reviewer commented that the stakeholder group and collaboration could be built out further to identify other applications of this technology and how it can answer existing data gaps.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said good follow up and continuation of the project.

Reviewer 2:

The reviewer remarked that the proposed future research plan focuses on addressing perceived near-term barriers, including high-bandwidth data transmission from roadside source to data center, and large-scale data processing and machine learning mobility system analysis and communication. The reviewer noted that for the remainder of FY 2018, the research will establish high-speed, real-time spatial data links between NREL and partner demonstration sites, and conduct additional research on energy equivalence metrics for intersection safety improvements. In FY 2019, the team will focus on machine learning methods using HPC to analyze and communicate spatial information and map spatial sensing technologies to specific mobility applications.

Reviewer 3:

The reviewer noted that FY 2018 work will be completed soon and the project budget overall is very small ($50,000). The reviewer noted that the authors mentioned a potential FY 2019 demonstration involving HPC, but the reviewer was unclear if it would be a different project as a follow-on.

Reviewer 4:

The project has clearly identified the remaining challenges and barriers including: data transmission bandwidth from roadside to data center; large-scale cloud sensing data processing and machine learning technologies for moving objects recognition, analysis, and communication; research on energy equivalence of safety improvements / crash avoidance. Ultimately, the goal is to achieve instrumented intersections, data fusion for visibility, develop a communication strategy for vehicles, pedestrians, others; and advance the knowledge and research base.

The reviewer detailed that proposed research for FY 2018 includes: establishing a high-speed, real-time spatial data link with partners; and performing energy equivalence of safety research. For FY 2019, proposed future research includes: creating machine-learning approaches with HPC to recognize, analyze, and communicate spatial information; and mapping spatial infrastructure sensing to applications that enhance mobility/energy efficiency and safety, including traffic signal control strategy, near-miss detection and prevention, and cybersecurity applications for CV/vehicle to infrastructure/infrastructure to vehicle.

The reviewer assessed that the proposed future research seems logical and directly addresses the identified barriers. As mentioned before, the reviewer believed that more detail on the criteria for the go/no-go milestone in FY19 would be beneficial. The reviewer noted that the team provided no discussion of risk mitigation through development of alternate development pathways.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer remarked assessing the mobility/energy performance potential of placing spatial sensors (i.e., LIDAR) at critical intersections is relevant to increasing efficiency of the transportation system and therefore reducing petroleum consumption. The reviewer said that a review of the current project findings will determine if a follow-on demonstration is warranted based on energy efficiency (petroleum) savings.

Reviewer 2:

The reviewer found that this project is relevant to VTO’s EEMS program in that connected and automated technologies can integrate smart infrastructures to enable drive smoothing and reduce traffic accidents and thereby decrease energy consumption. The reviewer said the project has highlighted the energy equivalence of safety improvements/crash avoidance. Specifically, the National Highway Safety Administration estimated in 2015 excess fuel per fatal crash for urban arterials to be 504 gallons, 102 gallons per injury crash, and 68 gallons of fuel per “property damage-only” crash.

Reviewer 3:

The reviewer remarked this project is relevant to DOE objectives in reviewing mobility system applications of spatial sensing technologies and assessing machine learning methods using HPC to analyze and utilize spatial information for supporting future mobility systems and other applications.

Reviewer 4:

The reviewer remarked, at the very least, this pilot will help generate some interesting data about traffic intersections that could be plugged into other traffic models.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked this is a small exploratory task that currently only has an allocation of $50,000. The reviewer said resources seem insufficient to fully explore the capability and feasibility of infrastructure spatial sensing at intersections.

Reviewer 2:

The reviewer found that the budget seems appropriate for length and depth of project.

Reviewer 3:

The reviewer observed an appropriate use of funds (only $50,000) for a quick-look project to investigate the feasibility of using spatial sensing in a stationary application and quantify the energy saving opportunity before additional and more significant DOE funding is invested.

Reviewer 4:

The reviewer said that project funding appeared appropriate for FY 2018 activities as described.

Presentation Number: eems054
Presentation Title: Infrastructure Impacts of SMART Technology: Data Analyses on Energy Use
Principal Investigator: John Beck (Idaho National Laboratory)

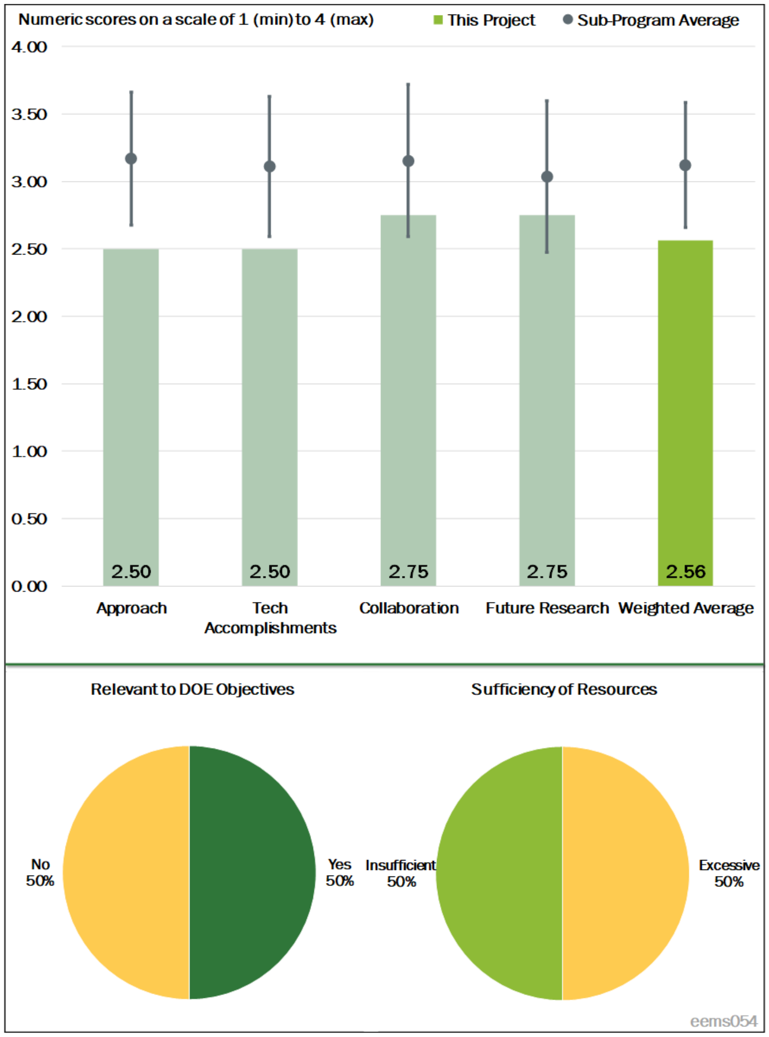

Figure 3-39 - Presentation Number: eems054 Presentation Title: Infrastructure Impacts of SMART Technology: Data Analyses on Energy Use Principal Investigator: John Beck (Idaho National Laboratory)

Presenter
John Beck, Idaho National Laboratory

Reviewer Sample Size
A total of two reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer said that the approach appears to be evolving at this point in the project, and the approach is somewhat vague so there is not much of one to critique.

Reviewer 2:
The reviewer remarked the approach needs more definition. The reviewer inquired what data analytics will be performed, and how will the team obtain the data.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer remarked the project is behind on some key aspects—particularly data accumulation, which will be challenging in many aspects.

Reviewer 2:
The reviewer said at this early stage of the project there is much to evidence to assess the technical accomplishments and progress.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer observed a good array of partners but looks like partnerships are largely for data collection purposes. The reviewer asked if there are any analytical partnerships.

Reviewer 2:

The reviewer stated the collaborative relationships for this project are evolving and need to be further solidified.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said seems like appropriate next steps.

Reviewer 2:

This reviewer has no argument that the steps outlined are logical to advancing the maturity of this project.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that it is important to understand how ACES will impact infrastructure requirements and spending.

Reviewer 2:

The reviewer commented the focus on this project appears to be on urban planning instead of mobility energy productivity. An example of the irrelevance of this project to DOE objectives is that it lists one of the primary barriers addressed by this work as, "Expansive community of relevant stakeholders." This reviewer has never seen stakeholder characteristics listed in the statement of DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer speculated that perhaps this project's budget could better be used pursuing other EEMS projects. The project presentation gives the impression that the project may be floundering.

Reviewer 2:

The reviewer remarked that given the slow progress, it seems possible that the budget for this project could surpass what has been requested.

Presentation Number: eems055
Presentation Title: Simulation Model Results for Energy and Mobility Impact of Behavioral Scenarios in POLARIS
Principal Investigator: Josh Auld (Argonne National Laboratory)

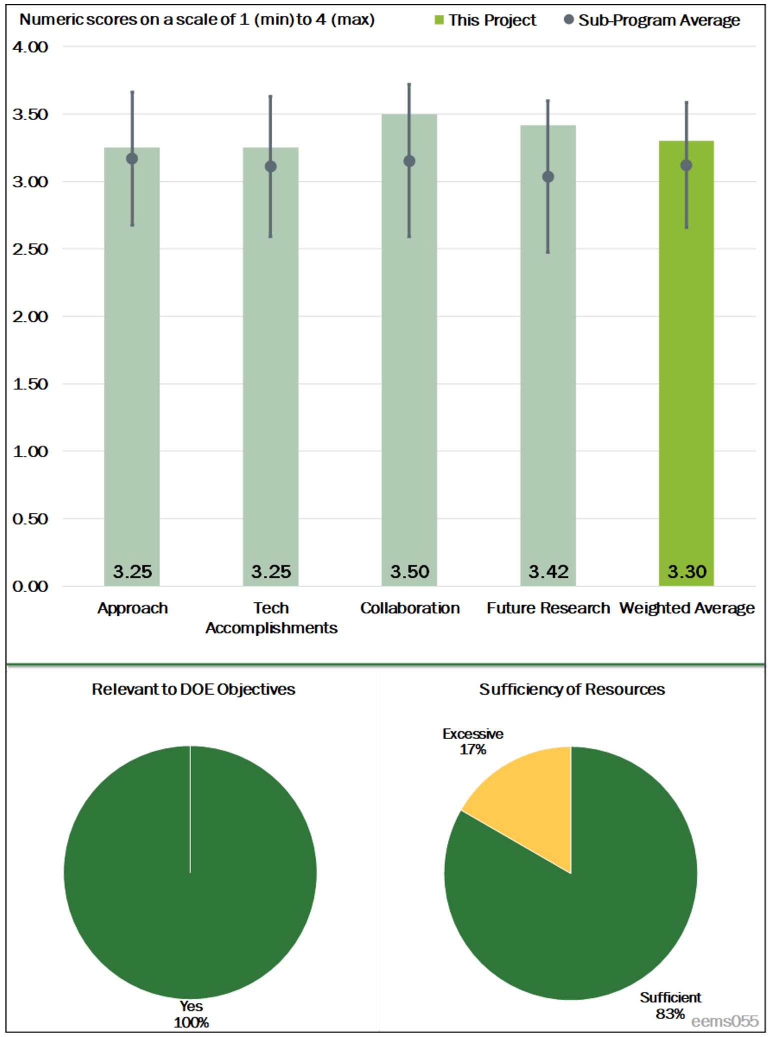

Figure 3-40 - Presentation Number: eems055 Presentation Title: Simulation Model Results for Energy and Mobility Impact of Behavioral Scenarios in POLARIS Principal Investigator: Josh Auld (Argonne National Laboratory)

Presenter

Josh Auld, Argonne National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the project approach is fairly comprehensive and well-suited to the scope of the proposed work. The level of detail that goes into addressing each question raised is impressive.

Reviewer 2:

The reviewer was not clear whether the model includes the influence of weather on mode choices. The reviewer thought the team should make very clear that these models are not meant to predict the future, but are more useful to study the expected changes that could be the outcome when the input scenarios are changed. In other words, any prediction of this model would be quite hard to confirm/verify.

Reviewer 3:

The reviewer remarked using existing models and data to do the research is a good approach.

Reviewer 4:

The reviewer remarked the outline of the approach to use simulation modeling is properly outlined, and it is critical to have the right assumptions for the driver behavior.

Reviewer 5:

The focus of this project is to demonstrate how consumer behavior interacts with new mobility technologies to potentially save energy. The project objectives identified are to: consider the behaviors of individual travelers at multiple timeframes; and assess the influence of traveler decisions on MEP for future mobility. The key goal is reducing uncertainty of MEP changes due to decision-making from VTO analysis. The reviewer indicated there is a high degree of interconnection between decision-making, transportation system performance, and development of smart mobility technologies.

According to the reviewer, the project identified high-level barriers, including: high uncertainty in technology deployment, functionality, usage, and impact at the system level; computational models, design, and simulation methodologies; lack of data on individual behaviors resulting from CAV adoption and usage; and integration of disparate model frameworks.

The reviewer detailed that the project approach incorporates three primary components: updating behavioral models in core tools (POLARIS and Autonomie) used for transportation and energy simulation; leveraging a variety of data sources within and outside of SMART; and developing and providing input to case studies and analyzing energy outcomes. The reviewer noted that significant detail is provided as to the activities under each of these components. Overall, the reviewer assessed that the project is well-designed, feasible, and appears to address many of the technical barriers. It would have been beneficial to more sharply define the project objectives and provide specific FY 2019 milestones.

Reviewer 6:

The reviewer really liked the approach to this problem and thought this project gets to the heart of whether CAV adoption and usage makes sense or not. What the reviewer would like to see clearly defined from this project is facts that can be used in the media. For example, there is a fuel savings of 1% if telecommuting moves from 2.6% to 5.6%. The reviewer pointed out the paper did not clearly outline this, but this was on the poster board.

The reviewer also observed the paper noted that there will be a significant time when CAVs are empty. The reviewer inquired what that means for energy costs, and how should that be improved. The reviewer asked whether, as such, there is a limit for CAVs.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented relative to project objectives, progress has been excellent. The additional building blocks in POLARIS for multi-modal travel and AV usage are key components to adapt it for use in answering the questions posed by the SMART Mobility activity.

Reviewer 2:

The reviewer said that the project appears to be on schedule achieving the milestones established to date. The project has achieved a significant number of technical accomplishments and the team has provided a substantial amount of detail. Specifically: First, modelling of telecommuting adoption and frequency behavior from survey data has found that flexible schedules, work trip distance, and travel time all increase telecommuting frequency, while low income decreased the likelihood of telecommuting. Second, the reviewer noted that ANL has developed and implemented a new multi-modal point-to-point router that is used to simulate non-auto trips and explore competition between modes. This routing algorithm is multimodal, intermodal, agent-based, and computationally efficient. The reviewer noted how ANL has generated the set of potential feasible mode choice options for each agent with enhanced heuristic filters to generate appropriated walk-to-transit and drive-to-transit routes. Third, the reviewer noted that ANL has developed a preliminary model with TNC estimated using a Federal Transit Administration (FTA) stated preference survey. Fourth, the reviewer noted that ANL developed a model for intra-household Level 5 AV and ride sharing. This model identifies the optimal number of privately owned autonomous vehicles for each household considering vehicle sharing, as well as ride sharing. Fifth, the reviewer noted that ANL analyzed time use and time valuation data as the disutility of travel time significantly influences travel. The value of time varies depending upon the data source and it is critical to understand the limitations of data, methods, and survey design. Sixth, the reviewer noted that ANL has implemented a time of day and activity duration choice model and developed key insights.

Additionally, the team used the POLARIS Chicago model to conduct case studies on the impact of telecommuting, including the effects of flex-work scheduling on telecommuting and energy use. The team found that flex work scheduling was somewhat effective in alleviating peak period congestion. The reviewer observed, overall, an extensive list of accomplishments.

Reviewer 3:

The reviewer remarked having the right assumptions, and leveraging available data helps in the maturity of the modeling.

Reviewer 4:

The reviewer said that results so far seem to have provided good insights into telecommuting behavior and impacts.

Reviewer 5:

The reviewer said that some of the key findings (telecommute model) appear to be intuitive and the reviewer supposed indirectly validate the model. The more interesting aspect of the findings is the actual relative magnitudes of the telecommute frequencies. As the reviewer mentioned in the response to Question 2, it is not clear whether the routing algorithm accounts for a change in the mode preference as a function of the weather condition. The reviewer pointed out this is the Windy City, and winter weather can be less than appealing. The reviewer found it is good that the model allows “random parameters” to represent heterogeneity, but that also means that the authors have another knob to control. The reviewer recommended it would be very helpful if the team listed all the acronyms used on a separate slide.

Reviewer 6:

The reviewer remarked this is a good start. The reviewer would like to see more exploration on items that were found, and how to improve the data to come to results. Also, the reviewer would like to see results defined, in a business sense, in an energy improvement (or not) sense, and dollarize where possible.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer very much so appreciated the collaboration, especially with the City of Chicago, which is at ANL’s back door.

Reviewer 2:

The reviewer remarked good outline of how the partners are working; the key is to share data that is reflective of real world.

Reviewer 3:

The reviewer observed that the project exhibits strong partnerships and collaborations with others including: ORNL, LBNL, FTA, Chicago Department of Transportation, University of Illinois at Chicago, and the University of New South Wales. Each entity provides a different expertise and/or access to specific modelling capabilities and real-world/surveyed data. The reviewer assessed that overall, the team is diverse and well-balanced.

Reviewer 4:

The reviewer said the project relies on a wide array of collaborators and information/study sources to get the required data for the features to be implemented.

Reviewer 5:

The reviewer said the national laboratories, Chicago Department of Transportation, and FTA have collaborated well.

Reviewer 6:

The reviewer said that this project takes in inputs from several other EEMS projects, and involves several national laboratory partnerships as well as partnerships with other organizations. This reviewer emphasized that any cross-talk between the LBNL team (BEAM) and the ANL team is notably absent, and that, of course, there is collaboration with the land use modeling team at LBNL.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that challenges are with having enough data and the assumptions behind it; to have a wide array of different drive scenarios

Reviewer 2:

The reviewer pointed out the important questions to be answered in the proposed future work are the project's reason for being. The challenges remaining to get to those answers appear clearly understood.

Reviewer 3:

The reviewer said that the authors are just scratching the surface here. Dig deeper, dollarize. The reviewer is looking forward to seeing what the authors find (with data) compelling or not in this very exciting space.

Reviewer 4:

The reviewer said that the project provides a strong synopsis of the remaining challenges and barriers, including: activity generation and how it will shift in response to CAVs is a key unknown in models; data limitations of many of the models and how they relate to future mobility technologies; the great variety of parameters controlling the behavior of responses of travelers that interact to create system results; and model integration challenges between systems operating at vastly different time scales. The reviewer said these barriers make sense and are informative.

The reviewer detailed as next steps for the project are to: connect to vehicle choice models for realistic fleet distribution; incorporate research into time use behavior and travel time valuations; improve traffic flow model; expand analysis to additional CAV technologies and shared use cases; and evaluate transferability for national level energy evaluations. The reviewer said that proposed future research includes: exploring activity generation models and changes under CAV scenarios while linking to time use analysis; extending telecommuting analysis looking at the impact of CAVs and connections between increased teleworking and freight delivery; integrating data and models from surveys about travelers' attitudes towards CAVs; extending mode choice and other behavioral analysis to include non-privately owned CAVs, including ridesharing, autonomous fleets, etc.; exploring connections between individual travel choices and land use; and conducting sensitivity analysis of key SMART Mobility metrics to various behaviors. The reviewer assessed that the proposed future work considers many of the behavioral barriers to the realization of SMART Mobility technologies and proposes a number of logical future activities to target. The reviewer said that the project does not specifically discuss alternate development pathways.

Reviewer 5:

The reviewer said the PI is going about systematically addressing all the weak links in the current project—that is not to say that the current project as it stands is not well-executed. The reviewer pointed out very nature of the project involves a large number of uncertainties, and the PI is working to reduce those.

Reviewer 6:

The reviewer pointed out the proposed sensitivity analysis is particularly critical.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer really enjoyed this presentation and work. The reviewer encouraged keep pushing for estimating/determining/modeling how people will behave in this new model of mobility.

Reviewer 2:
The reviewer said that with MEP as a key metric of the EEMS program, this project links together a diverse set of projects to evaluate the metric based on individual behavior.

Reviewer 3:
The reviewer found that the project supports DOE objectives by providing a powerful tool to study possible energy consumption outcomes at the transportation system level. This will help DOE to set appropriate future policy objectives.

Reviewer 4:
The reviewer said the combined analysis of energy use and mobility impacts of traveler behavior through mobility decision modeling and transportation system simulation is critical to DOE objectives.

Reviewer 5:
The reviewer found that this project is relevant as behavior is a high source of uncertainty with regards to the impact of advanced mobility, and there is limited data on behavioral responses to CAVs and other future mobility technologies. The reviewer detailed that this project seeks to reduce uncertainty around energy use forecasts for SMART Mobility technologies and other traveler options. Through mobility decision modeling and transportation system simulation, this project improves the understanding and prediction of the impact of traveler behavior. The reviewer said by doing so, more informed smart mobility decisions can be made, as well as better estimates of ensuing energy and mobility impacts.

Reviewer 6:
The reviewer said the work is important to have a modeling tool that predicts drive behavior.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Resources appear to be sufficient for FY 2018, and FY 2019 work funding is not indicated but the project is worthy of continuation.

Reviewer 2:
The reviewer commented the resources ($1.35 million total for FY 2017-FY 2019) are sufficient to achieve the project's objectives and stated milestones.

Reviewer 3:
The reviewer pointed out the funding level for FY 2019 appears to be somewhat higher than that for FY 2017 and FY 2018, and should be sufficient to accomplish the remaining list of tasks.

Reviewer 4:
The reviewer said that data are critical to support the effort.

Reviewer 5:
What happened is in the author's budgeting process, the reviewer saw only a total. The reviewer did not see anything relating to manpower days, $/hour, etc. which is what one typically sees in engineering management. The reviewer asked if there is something MORE that the authors need from constituents to be successful, say

from the City of Chicago and the FTA. The reviewer asked what more do the authors need to be successful in their endeavor. The reviewer saw in the Barriers to the Project that the authors are lacking data on individual behaviors relating to CAV adoption and usage. The reviewer asked, well, what do the authors need to get to the data, and what data do the authors need. Define it. Figure it out. Go after it.

Reviewer 6:

The reviewer said there seems to be a lot of funding for the level of work actually being done.

Acronyms and Abbreviations

ABM	Activity-based model
ABMS	Agent-based modeling and simulation
ACC	Adaptive cruise control, automated cruise control
ADAS	Advanced Driver Assistance System
ACES	Automated, connected, efficient, and shared; automated, connected, electric, and shared
AES	Automated electric shuttle
AMBER	Advanced Model Based Engineering Resource
AMD	Automated mobility districts
AMR	Annual Merit Review
ANL	Argonne National Laboratory
APRF	Advanced Powertrain Research Facility
ARPA-E	Advanced Research Projects Agency-Energy
ATM	Active traffic management
AV	Automated vehicle
BEAM	Behavior energy autonomy mobility
BEV	Battery electric vehicle
CAC	Cooperative automated control
CACC	Cooperative adaptive cruise control
CAFÉ	Corporate Average Fuel Economy
CAN	Controller area network
CAV	Connected autonomous vehicle, connected and automated vehicle
CO_2	Carbon dioxide
CV	Connected vehicle
DoE	Design of experiment
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation

DSRC	Dedicated short-range communications
DWPT	Dynamic wireless power transfer
Eco-CACC-I	Eco-Cooperative Adaptive Cruise Control-I
EEMS	Energy-Efficient Mobility Systems
EPA	U.S. Environmental Protection Agency
EV	Electric vehicle
FAA	Federal Aviation Administration
FASTSim	Future Automotive Systems Technology Simulator
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FTA	Federal Transit Administration
FY	Fiscal Year
GPS	Global positioning system
HD	Heavy-duty
HDV	Heavy-duty vehicle
HEV	Hybrid electric vehicle
HPC	High-performance computing
HWFET	Highway Fuel Economy Test
Hz	Hertz
ICE	Internal combustion engine
INL	Idaho National Laboratory
iTiC	International Transportation Innovation Center
ITS-JPO	Intelligent Transportation System Joint Program Office
L4	Level 4 high automation
L5	Level 5 full automation
LA	Los Angeles
LANL	Los Alamos National Laboratory
LBNL	Lawrence Berkeley National Laboratory

LD	Light-duty
LDV	Light-duty vehicle
LIDAR	Light imaging, detection, and ranging
LIGO	Laser Interferometer Gravitational-wave Observatory
LLNL	Lawrence Livermore National Laboratory
LSTM	Long short-term memory
MA3T	Market Acceptance of Advanced Automotive Technologies
MaaS	Mobility-as-a-system, mobility-as-a-service
MD	Medium-duty
MDV	Medium-duty vehicle
MEP	Mobility energy productivity
ML	Machine learning
MOC	Model predictive control
MORPC	Mid-Ohio Regional Planning Commission
MOU	Memorandum of Understanding
MOVES	Motor Vehicle Emission Simulator
MPC	Model-predictive control
MPO	Metropolitan Planning Organization
NDA	Non-disclosure agreement
NHTSA	National Highway Traffic Safety Administration
NPP	Nuclear power plant
NRC	National Research Council of Canada
NREL	National Renewable Energy Laboratory
NSF	National Science Foundation
O-D	Origins-destination
ODOT	Ohio Department of Transportation
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory

OTA	Over-the-air
PEV	Plug-in electric vehicle
PHEV	Plug-in hybrid electric vehicle
PI	Principal Investigator
PNNL	Pacific Northwest National Laboratory
POLARIS	Planning and Operations Language for Agent-based Regional Integrated Simulation
Q&A	Question and answer
R&D	Research and development
RL	Reinforcement learning
RMS	Root mean square
ROI	Return on investment
SAE	Society of Automotive Engineers
SMART	Systems and Modeling for Accelerated Research in Transportation
SPRINGS	Statistical Planning for Resilience in Next Generation Systems
SUV	Sport utility vehicle
SVTrip	Stochastic vehicle trip
TARDEC	U.S. Army Tank Automotive Research, Development and Engineering Center
TAZ	Travel analysis zone
TNC	Transportation network company
TRANSNET	Traveler Response Architecture using Novel Signaling for Network Efficiency in Transportation
TRL	Technology Readiness Level
TSDC	Transportation Secure Data Center
TTI	Texas Transportation Institute
UC	University of California
UDDS	Urban Dynamometer Driving Schedule
UE	User equipment
UIC	University of Illinois at Chicago

UMD	University of Maryland
UNR	University of Nevada, Reno
UPS	United Parcel Service
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
VATT	Vehicle average travel time
VIL	Vehicle-in-the-loop
VMT	Vehicle miles traveled
VTO	Vehicle Technologies Office

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4. Electrification Technologies

To strengthen national security, enable future economic growth, support energy dominance, and increase transportation energy affordability for Americans, the Vehicle Technologies Office (VTO) funds early-stage, high-risk research. The research will generate knowledge that industry can advance to deploy innovative energy technologies to support affordable, secure, reliable and efficient transportation systems across America. VTO leverages the unique capabilities and world-class expertise of the national laboratory system and works with partners across industry and academia to develop new innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures and better powertrains; and energy efficient mobility technologies and systems, including connected and automated vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement. VTO is uniquely positioned to address early-stage challenges due to its strategic research partnerships with industry (e.g., the U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise. These partnerships prevent duplication of effort, focus U.S. Department of Energy (DOE) research on the most critical research and development (R&D) barriers, and accelerate progress. VTO focuses on research that industry either does not have the technical capability to undertake on its own—usually because there is a high degree of scientific or technical uncertainty—or it is too far from market realization to merit sufficient industry emphasis and resources.

The Electrification R&D effort focuses on early-stage research to understand the potential impacts of electric vehicle (EV) charging on the nation’s electric grid. Electric Drive Research focuses on early stage research of extreme high-power density motor and power electronics that have the potential to enable radical new vehicle architectures by dramatic volume/space reductions and increased durability and reliability.

Subprogram Feedback

DOE received feedback on the overall technical subprogram areas presented during the 2018 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram’s activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied.

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year?

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: bat918
Presentation Title: Battery and Electrification R&D Overview
Principal Investigator: Steve Boyd (U.S. Department of Energy)

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:
Yes, the program was covered to meet the needs of this reviewer. The material gave a very good overview of the DOE program and goals, and addressed the issues.

Reviewer 2:
The reviewer stated yes, and commented that the speaker did an excellent job of covering all facets of the battery and electrification research and development (R&D) efforts. Key challenges in each of the main areas of technology and how they were being addressed by ongoing research was discussed. This reviewer reported that the following were covered: lithium (Li)-ion and non-lithium battery cell development, including new low cobalt (Co) cathode and intermetallic alloy anode work; electric drive developments at higher voltages and lower costs; and grid issues, including fast charging and cybersecurity. A strong case was made for the need to reduce battery cost and charging time, along with the need to reduce cost and increase efficiency of the traction drive system to ensure large market penetration of electric drive vehicles (EDVs). This reviewer commented that concurrent grid infrastructure needs to support widespread acceptance of electric vehicles (EVs) was also addressed. As far as specific technologies are concerned, the presenter did a particularly good job of covering the wide array of outstanding work in the area of power electronics and motors for vehicle electrification.

Reviewer 3:
The reviewer responded positively and explained that battery life must be properly predicted for projects to be funded in the extreme fast charge Li-ion cell area. This reviewer inquired whether it is possible to develop a degradation model of various battery components so that a predictive model is developed, gets shared with stakeholders, and is tested to validate the developed model.

Reviewer 4:
This reviewer indicated yes and suggested the following strategy adjustments: cost of electric vehicle batteries to less than $100/kilowatt-hour (kWh) and $6/kilowatt (kW) for a 100 kW peak Electric Drive System (EDS); breakout targets by technology areas (e.g., motor, inverter, battery package, controls, and thermal systems); and breakout targets for hybrid electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV), performance EV, and passenger EV.

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Reviewer 1:
The reviewer responded positively and asserted that there is an excellent balance. The presentation addressed the very near-term 2020 to the longer-term 2030 goals, and provided future roadmap indicators for the technologies being reviewed.

Reviewer 2:
This reviewer stated yes. There is an appropriate balance with all three areas well covered, including nearer-term Li-ion battery development and electric drive research focused on cost reduction; mid-term advanced cell battery, high-voltage electric drive, two-phase cooling, multiphysics integration, and grid integration work; and long-term research on extreme fast charging, new materials development, and cybersecurity,

Reviewer 3:
The reviewer commented that there is a need to make some adjustments. Regarding $6/kW for a 100 kW peak, the reviewer provided the following link to show that HEV sales are slowing (down 19.0%) and strong electric

plugged xEVs are increasing (up 46.0%). The reviewer cited an Argonne National Laboratory study of light-duty EDV sales update (http://www.anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates). With this in mind, the reviewer stated that future targets need to address the higher power requirements for battery, power electronics, and electric drive. Further, this reviewer noted that 100kW is low as a reference point for the future.

Reviewer 4:

This reviewer indicated yes. For wide bandgap (WBG) devices, the reviewer commented that it is necessary to cover voltage range from 48 volt (V) to 1,700V. The reviewer suggested that development of cost and performance optimized silicon carbide (SiC) power package could be one of the long-term (5 years) research goals.

SiC and gallium nitride (GaN) devices are far smaller than Si devices. Therefore, to keep inverter foot-print optimized and smaller, the reviewer explained that it is necessary to have an Application-Specific Integrated Circuit (ASIC) for gate driver circuit that should consist primarily of gate driver circuitry, including isolated power supplies and their watchdogs. The reviewer suggested this could be a mid-term goal and could raise the possibility of wide acceptance of SiC and GaN power converter technology for EVs, HEVs, PHEVs, etc.

Question 3: Were important issues and challenges identified?

Reviewer 1:

This reviewer stated yes, and noted that critical issues included cost reduction, power density increases, increased charging speed, grid integration, cybersecurity, and methods to address range anxiety (e.g., longer battery life and improved infrastructure).

Reviewer 2:

In this overview presentation, the reviewer observed several areas were addressed that impact the future of vehicle electrification. Each area had technical issues and challenges that needed to be addressed, which were done to this reviewer’s satisfaction.

Reviewer 3:

The reviewer stated yes, except for how manufacturing will be advanced to support project activities dedicated to achieve 2025 power density and cost targets for electric drive technologies.

Reviewer 4:

This reviewer identified key emerging challenges on the horizon. Firstly, marriage of autonomous with EV means that power management of the low voltage power bus has become safety critical and a challenge in the increased required power for all of the electric actuation and sensing, which could be more than 5kW. Secondly, the reviewer noted that electrical, battery, and component thermal management aspects for extreme fast charging are certainly needed as a future challenge. Finally, this reviewer highlighted the influence of fast charge on graphite life, nickel manganese cobalt oxide (NMCxxx), Si, or silicon oxides (SiO_x).

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:

The reviewer responded positively and noted that plans to address critical issues and challenges included cooling and multiphysics integration techniques to permit cost reduction and electric drive power density increases. New charger designs and battery cell materials were also proposed for increased charging speed, along with programs to improve grid integration and infrastructure.

Reviewer 2:

This reviewer stated yes, the plans for addressing the issues and challenges associated with the different technologies were identified. The presentation also provided the funding scheduled to support that work. The reviewer further highlighted that one major and key method identified involved forming collaborative teams that included the various labs and industry.

Reviewer 3:
The reviewer remarked that plans were somewhat identified for addressing issues and challenges, and suggested that plans may need minor or major changes as research progresses to achieve 2025 targets.

Reviewer 4:
This reviewer commented to continue U.S.-based WBG based component development—Tesla now has in its Model 3—and suggested this should be supplied and implemented by somehow leveraging overall domestic capability. The reviewer then referenced battery fast charge as related to electrochemistry and thermals. Regarding battery cost, the reviewer noted low cost chemistry (e.g., lithium manganese oxide [LMO]), and suggested to consider funding original equipment manufacturer (OEM) or supplier-based battery cell prototype equipment to speed learning in domestic locations.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:
Progress from last year was somewhat benchmarked against 2016-2017, as indicated by this reviewer. The trend tended toward progress over a larger timeframe that highlighted steady growth based on technology developments.

Reviewer 2:
This reviewer remarked that progress was somewhat clearly benchmarked against the previous year. For example, the reviewer highlighted a very nice chart showing the reduction in battery cost per year, and suggested that adding a full chart of the major accomplishments in the previous year, the current year, and the planned upcoming year would be nice.

Reviewer 3:
The reviewer stated yes, from a budget perspective, but was unsure whether this could be extrapolated to a technology-based progress. The reviewer suggested it might be worthwhile to have a perspective similar to the Advanced Combustion Systems team, which shows progress in emissions, power, power density, and 0-60 miles per hour (MPH) vehicle performance over time.

Reviewer 4:
This reviewer reported that 2020 and 2025 targets are quite different.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:
The key goal of the VTO office, as indicated by this reviewer, is to make electric drive vehicles competitive with fossil fuel powered vehicles in all aspects, particularly performance, cost, and overall life. The reviewer remarked that the projects and plans, as outlined, address the technical issues that need to be overcome to meet those goals.

Reviewer 2:
This reviewer stated yes, the projects in this technology area are all aimed at reducing cost, enhancing performance and efficiency, and improving the driving experience (e.g., increasing range, reliability, and security) to promote widespread EV acceptance and thereby minimize carbon emissions and fossil fuel use.

Reviewer 3:

The reviewer indicated that the projects in this technology area somewhat address the broad problems and barriers that VTO is trying to solve, and noted that projects should have a clear pathway for commercialization.

Reviewer 4:

This reviewer responded yes, generally, and recommended a continued focus to get performance up and cost down. One gap the reviewer identified is the marriage of autonomous with EV, which means that power management of the low voltage power bus has become safety critical and a challenge in the increased required power, Automotive Safety Integrity Level (ASIL) D safety, and power management for all of the electric actuation and sensing. The reviewer added that the required could be even more than 5kW.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:

The reviewer remarked yes; focus is maintained in the most fruitful areas for research. This reviewer observed excellent management at all levels from Steven Boyd, the Program Manager, who is an exceptional leader, to his experienced and expert team, especially Susan Rogers, who leads the electric drive efforts.

Reviewer 2:

This reviewer agreed that the program area appears to be focused, well-managed, and effective in addressing VTO needs. The reviewer reported that the presentation material outlines the areas that will address current, near-term, and future goals. The material covered areas that are needed on the vehicle side as well as much of the infrastructure concerns.

Reviewer 3:

The reviewer responded positively and commented that, in electric machine R&D work, material properties should be modeled to predict how new material will perform for various mission profiles (tow-speed characteristics) required by EVs, HEVs, PHEVs, etc.

Reviewer 4:

This reviewer asserted that an initiative is needed to attract the new and emerging EV companies to participate and suggested that DOE at least make some focused visits to those new companies to collaborate.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:

The reviewer expressed that the projects cover a wide range of topics, but are all complementary and focused toward electric vehicle improvement. Projects focused specifically on critical challenges include those related to design, packaging, thermal management, and reliability of innovative chargers and batteries for fast charging and for the grid infrastructure to support them. This reviewer explained that projects were well supported and had a nice balance of innovation and practicality that permitted significant and achievable progress in a reasonable time.

Reviewer 2:

One area that the reviewer identified was the need to have more visible support and/or input from the U.S. Department of Transportation (DOT). That involvement is undoubtedly there, but it was not clearly presented. The work with batteries was a focus of this reviewer, who indicated that the work in that area continues to push the envelope of understanding the issues and resolving them.

Reviewer 3:

This reviewer asserted that cost is key. Although there could be some more detailed trade-off on power density versus cost and manufacturability to meet cost, the reviewer commented that it will continue to lag in adoption without profitable electrification technology.

Reviewer 4:

This reviewer opined that there is too much focus on electric machine technology and little focus on inverter technology. The reviewer advised that attention to battery technology with a clear focus towards commercialization should be given due attention.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:

The reviewer indicated that the projects are novel and represent innovative ways to approach solutions to the issues involved. Further, this reviewer observed a multi-prong collaborative task force with a single mission, using analytical and testing tools from several labs is being used, which is both novel and innovative.

Reviewer 2:

This reviewer stated yes and highlighted some of the more novel approaches: microporous silicon anodes; Co-free cathodes; fundamental materials characterization of Li cells for extreme fast charging; use of multiphysics for device and package integration; two-phase cooling; and high voltage, WBG power converters.

Reviewer 3:

The reviewer agreed that these projects represent novel and/or innovative ways to approach these barriers. Alternative and variant cooling methods including phase-change cooling related projects should be funded to realize a power-dense air-cooled power converter, which this reviewer asserted will support adoption of the WBG technologies.

Reviewer 4:

Regarding extreme fast charging, this reviewer explained that, perhaps, the critical enabler of 800V max batteries is not so novel or innovative. Of course, the reviewer continued, this then drives needed work in high voltage (HV) power electronics and electric drives.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:

This reviewer stated yes; each of the projects has identified leaders in the field for collaboration. The level of industrial, academic, and government laboratory interactions in this program is impressive and the partners chosen are recognized experts.

Reviewer 2:

The reviewer responded positively and asserted that vehicle OEMs, battery manufacturers, national laboratories, and parts manufacturers for the battery manufacturers are all involved.

Reviewer 3:

This reviewer opined that industry, university, and DOE lab partnership should be encouraged to solve problems perceived as difficult and/or impossible.

Reviewer 4:

The reviewer commented that, generally, getting major OEMs is key. However, the reviewer indicated that there could be some sort of initiative needed to attract new and emerging EV companies to participate. This reviewer suggested that DOE at least make some focused visits to those new companies to collaborate.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:

The reviewer responded positively and observed regular, arranged meetings with updates that are provided. This reviewer further commented on dynamic direction and support that is delivered based on progress.

Reviewer 2:

This reviewer stated yes and suggested that industry, university, and DOE national laboratory partnerships should be further encouraged to solve problems perceived as difficult and/or impossible.

Reviewer 3:

Generally, the reviewer reported significant evidence of strong collaboration with industry and academia, as well as other government laboratories, though it depends on the project. Each partner is supplying a key appropriate aspect of each project, whether new materials, design expertise, modeling expertise, components for test, or facilities.

Reviewer 4:

The reviewer noted a basic model focus on having OEMs and suppliers build functional prototypes. This reviewer also observed labs and universities on materials, basic research, and studies.

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:

The reviewer remarked that gaps have been identified, but are a risk level that allows them to exist until the key items are addressed. This reviewer added that the focus has to be on areas that will drive success rather than areas that may have some limited value.

Reviewer 2:

Regarding the design for "Giga-Watt-Hr" (GWh) production of battery cells and packs, this reviewer commented that electrochemistry is important, but will need the balance with manufacturing at large scale to be a factor. Although reducing Co and other materials saves money, so does a more efficient manufacturing technique.

Reviewer 3:

This reviewer indicated that it seems like Li-ion batteries are tracking quite well with the desired trends for cost reduction, as this is happening year after year. In the category of beyond Li-ion projects, there should be some focus to improve Li-Ion technology too; this is needed for large scale adoption of EVs. The reviewer opined that car drivers still have battery reliability in mind when they hit car dealers to buy an EV.

Reviewer 4:

The reviewer recommended other areas to investigate, including the following: three-dimensional (3-D) packaging, including additive manufacturing; electro-thermal-mechanical-reliability co-design; high voltage thin film insulators; and new WBG semiconductors (e.g., gallium oxide [GaO], diamond).

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:

The reviewer asserted that key topics to make this technology reach stated goals are being addressed.

Reviewer 2:

This reviewer commented that future targets need to address the higher power requirements for battery, power electronics, and electric drive, and further highlighted that 100 kW is low as a future reference point.

Reviewer 3:

According to this reviewer, some attention should be given to enabling technologies for inverters, such as packaging material; thermal management materials, including advanced cooling technologies for inverters; inverter interconnects; motor; and connectors, etc.

Reviewer 4:

The reviewer referenced prior comments.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:

This reviewer recommended ensuring state of charge (SOC) and state of health (SOH) algorithms during these events as related to extreme fast charging.

Reviewer 2:

The reviewer suggested other potential areas that may need funding to meet the overall goal of vehicle electrification.

Reviewer 3:

The reviewer commented that eliminating resistive contacts within an inverter and between motor and inverter should be given due consideration. The reviewer explained that, often, Electric Drive (ED) fails or life of ED reduces due to heating of various inter connects within ED system.

Reviewer 4:

This reviewer referenced prior comments.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:

The involvement of the different national laboratories and OEMs has allowed for a multitude of counselors to be involved in evaluating and suggesting all viable approaches that this reviewer could envision.

Reviewer 2:

The program’s current approach was described by this reviewer as well on track.

Reviewer 3:

This reviewer was unable to offer any quality ideas.

Reviewer 4:

The reviewer remarked that capturing requirements early should be encouraged for each project. Further, this reviewer suggested accomplishing this by identifying a specific application of underlying technology being developed through DOE-VTO funding. Often, R&D work goes somewhat satisfactorily; however, research faces the valley of death due to lack of adoption when research outcomes fall short in addressing application needs. The reviewer opined that this can be addressed by encouraging industry partnership with a commitment to demonstrating technology in an identified application.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:

The reviewer commented that this presentation did exactly what was needed—it gave a very good overview of the programs involved, their tasks, goals, and accomplishments. This presentation was also effective as it highlighted some of the key issues that must be overcome.

Reviewer 2:
The reviewer stated none.

Reviewer 3:
Continuing focus on the most critical constraints to a widespread market penetration of electric vehicles (i.e., cost, range, and reliability) was recommended by this reviewer.

Reviewer 4:
This reviewer suggested that increased involvement of industry reviewers should be considered during selection of projects for DOE-VTO funding. If possible, university and DOE national laboratory projects should have industry advisors with application-oriented mindsets. Otherwise, continued this reviewer, DOE-VTO funded R&D work runs the risk of falling into the valley of death.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0*). In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 4-1—Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt015	Part Development of Radically Enhanced alnico Magnets (DREaM) for Traction Drive Motors 1	Iver Anderson (Ames Laboratory)	4-15	2.86	3.00	3.29	2.57	**2.95**
elt049	Advanced High-Performance Computing (HPC) Multiphysics Modeling of Motors and Materials	Jason Pries (ORNL)	4-21	3.17	3.33	3.08	3.17	**3.24**
elt054	Drivetrain Performance Improvements Techniques	Gui-Jia Su (ORNL)	4-25	3.20	3.30	3.00	3.00	**3.20**
elt071	Ultraconducting Copper	Tolga Aytug (ORNL)	4-29	3.08	3.17	2.92	2.75	**3.06**
elt074	Non-Rare Earth Electric Motors †	Tsarafidy Raminosoa (ORNL)	4-34	3.17	3.00	3.00	2.83	**3.02**
elt075	Electric Motor Thermal Management	Kevin Bennion (NREL)	4-37	3.36	3.29	3.21	3.07	**3.27**
elt077	Innovative Converters and Chargers †	Veda Galigekere (ORNL)	4-42	3.38	3.13	3.13	3.00	**3.17**
elt078	Power Electronics Thermal Management	Gilbert Moreno (NREL)	4-45	2.93	2.79	3.00	2.71	**2.84**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt079	Advanced Multiphysics Integration Technologies and Designs	Emre Gurpinar (ORNL)	4-50	3.00	3.13	3.13	3.25	**3.11**
elt080	Performance and Reliability of Bonded Interfaces for High-Temperature Packaging †	Paul Paret (NREL)	4-53	3.17	3.50	3.33	3.33	**3.38**
elt089	Motors Assessing the North American Supply Chain for Traction Drive Inverters, and Batteries for Class 3-8 Hybrid Electric and Plug-In Electric Commercial Vehicles	Chris Whaling (Synthesis Partners)	4-56	3.00	2.75	3.00	2.63	**2.83**
elt090	Soft Dual-Phase Non-Magnetic Laminates for Low-Cost-Reduced Rare-Earth Containing Electrical Machines	Francis Johnson (GE Global Research)	4-60	3.25	2.75	3.00	3.00	**2.94**
elt091	Cost-Effective 6.5% Silicon Steel Laminate for Electric Machines	Jun Cui (Iowa State U.)	4-62	3.13	3.25	3.13	2.88	**3.16**
elt092	Wound Field and Hybrid Synchronous Machines for Electric Vehicle Traction with Brushless Capacitive Rotor Field Excitation	Ian Brown (Illinois Institute of Technology)	4-66	2.88	3.13	3.13	3.00	**3.05**
elt093	High-Speed Hybrid Reluctance Motor with Anisotropic Materials	Edwin Chang (General Motors)	4-70	2.50	2.50	2.75	2.88	**2.58**
elt094	Development and Demonstration of Medium- and Heavy-Duty Plug-In Hybrid Work Trucks	John Petras (Odyne Systems)	4-73	3.00	3.00	3.20	2.80	**3.00**
elt095	Vehicle-to-Grid Electric School Bus Commercialization Project	Andy Moore (Blue Bird Corp.)	4-78	2.90	3.10	3.10	3.00	**3.04**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt115	Zero-Emission Drayage Truck Demonstration (ZECT I)	Phil Barroca (SCAQMD)	4-83	3.42	3.42	3.75	3.17	**3.43**
elt116	Zero-Emission Delivery Vehicle Deployment	Andrew DeCandis (Houston-Galveston Area Council)	4-88	2.80	2.80	2.90	3.10	**2.85**
elt158	Zero-Emission Cargo Transport II: San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project	Joseph Impullitti (SCAQMD)	4-93	3.00	3.10	2.90	2.80	**3.01**
elt187	Vehicle Comprehensive Assessment of On- and Off-Board-to-Grid Technology Performance and Impacts on Batteries and the Grid	Sunil Chhaya (EPRI)	4-98	3.20	3.30	3.60	3.30	**3.31**
elt188	Bi-Directional Wireless Power Flow for Medium-Duty Vehicle-to-Grid Connectivity	Steven Sokolsky (CALSTART)	4-102	3.70	3.40	3.40	3.30	**3.46**
elt189	Electric Truck with Range-Extending Engine (ETREE)	John Kresse (Cummins)	4-106	3.10	2.90	3.00	2.90	**2.96**
elt190	Medium-Duty Urban Range Extended Connected Powertrain (MURECP)	Alexander Freitag (Bosch)	4-110	2.88	3.13	3.00	3.13	**3.05**
elt191	Medium-Duty Vehicle Powertrain Electrification and Demonstration	Wiley McCoy (McLaren)	4-113	3.20	3.20	3.40	2.60	**3.15**
elt193	Grid Modernization Laboratory Consortium: Vehicle-to-Grid Integration Pathway (GM0062)	Rick Pratt (PNNL)	4-117	3.38	3.25	3.13	3.13	**3.25**
elt194	Grid Modernization Laboratory Consortium: Systems Research for Standards and Interoperability (GM0085)	Don Scoffield (INL)	4-120	3.38	3.25	3.25	3.25	**3.28**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
elt196	Grid Modernization Laboratory Consortium: Diagnostic Security Modules for Electric Vehicle-to-Building Integration (163)	Kenneth Rohde (INL)	4-123	3.60	3.60	3.50	3.60	**3.59**
Overall Average				**3.13**	**3.13**	**3.16**	**2.99**	**3.12**

† Denotes poster presentation.

Presentation Number: elt015
Presentation Title: Development of Radically Enhanced alnico Magnets (DREaM) for Traction Drive Motors, Part 1
Principal Investigator: Iver Anderson (Ames Laboratory)

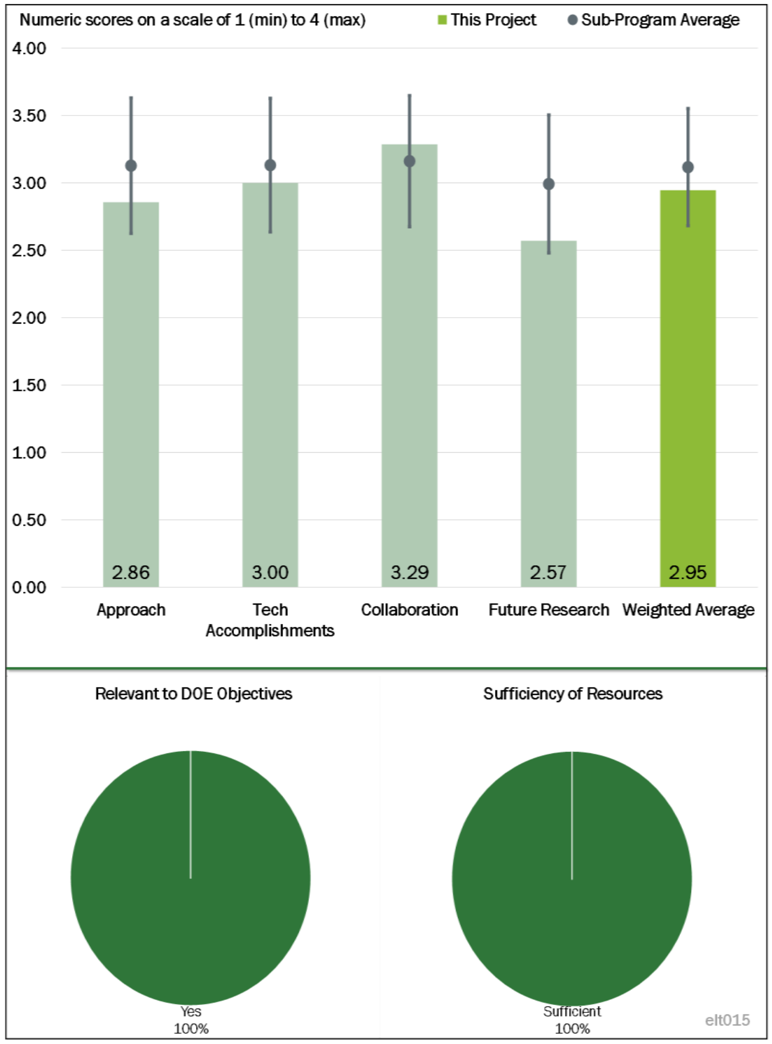

Figure 4-1 - Presentation Number: elt015 Presentation Title: Development of Radically Enhanced alnico Magnets (DREaM) for Traction Drive Motors, Part 1 Principal Investigator: Iver Anderson (Ames Laboratory)

Presenter

Matt Kramer, Ames Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer called this a highly integrated project with modeling and advanced characterization that is scheduled to end in September 2018. The objective is to design and synthesize a high-energy product aluminum-nickel-cobalt-(AlNiCo) permanent magnet (PM) competitive with rare earth (RE) PM (residual induction [Br] in excess of 0.8 tesla (T) and intrinsic coercive force (Hci) in excess of 2,500 Oersted [Oe]). The reviewer explained that the overall approach includes two different activities: near-term, non-RE magnets and long-term, non-RE magnets targeting 20 Megagauss Oe (MGOe) energy product. Specifically, the reviewer pointed out that the approach includes fabrication of well-controlled bulk magnet samples with enhanced grain alignment and energy product and with mechanical properties, all exceeding commercial AlNiCo magnets.

Reviewer 2:

The reviewer remarked that the program seeks to enhance the magnetic properties of AlNiCo magnet material to make it more competitive with RE-based magnets in terms of achieving similar performance. The targets for Hci and Br are laid out clearly and were defined with input from industry. The technical barriers are well known and the resources are well suited to address the problem. The reviewer asserted that the project team is taking an analysis-based approach along with experiments and testing at a scale that can be implemented in a final product. The reviewer thought that all of these steps make this approach well thought out and risk reduced.

Reviewer 3:

The reviewer indicated that the project lacks a clear understanding of primary traction motor applications needs and competing technologies (grain boundary diffused PM and heavy rare earth [HRE]-free PM).

Reviewer 4:

The reviewed stated that this effort of developing higher coercivity AlNiCo has been ongoing for a long time and it is not clear that there is a well-defined path of reaching coercivity/energy product levels that can ultimately enable competitive RE-free designs. The reviewer said that more quantification of motor performance enabled by the achieved AlNiCo properties so far (as well as targeted properties) should be provided.

Reviewer 5:

The reviewer commented that performance of non-rare-earth magnets drop with an increase in temperature. This could lead to significant variations from one electric machine to the next electric machine produced using non-rare-earth magnets. In general, for EV applications, the electric machine is characterized; however, the significant variation in magnetic properties of the non-rare-earth magnet cannot be adequately addressed by characterization.

Reviewer 6:

The reviewer expressed concern that the project does not consider how this work can translate into something competitive with today's strong PM machines desired by industry that are free of HRE materials.

Reviewer 7:

The reviewer asserted that the objectives for this project are not clearly defined. The Milestones slide shows as an objective the design of a high energy product AlNiCo PM competitive with RE PM (cost/MGOE/kilogram [kg]). But, the reviewer noted, the key deliverables and go/no-go decision point set a much easier target, which is to design an improved magnet (0.8T, 2,500 Oe) only exceeding conventional AlNiCo 8 or 9. The reviewer questioned whether a magnet with these properties could support a motor design that meets the DOE 2025 power density targets.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer discussed the technical accomplishments that included cluster expansion and Monte Carlo simulations guiding annealing and agreeing with microstructure analysis (theory and modeling), magnetic field anneal optimization of coercivity (synthesis of bulk magnetic samples), and achievement of full-size, complex-shaped magnets. Additionally, in terms of mechanical and thermal properties, the reviewer stated that sintered magnets show enhanced strength to improve assembly reliability and permit high motor speeds.

Reviewer 2:

The reviewer said that half of the goals have been achieved, Hci was shown to be improved to above the target based on actual material development and testing. Achieving the other goal of Br greater than .8 T is within reach as it is a matter of grain alignment and improving the magnetic alignment/annealing process. The reviewer commented that process development takes time, and considering the steps involved in this type of development, the program is going well from an execution standpoint.

Reviewer 3:

The reviewer noted that the principal investigator (PI) has carried out simulations and experimental work to accomplish project milestone

Reviewer 4:

The reviewer indicated that progress has been made and the materials work is well thought-out.

Reviewer 5:

The reviewer said that when considering the premise that the new magnet material only has to be better than conventional AlNiCo 8 or 9, good progress has been made. It would be useful if the PIs could show the new AlNiCo material in comparison to a very low-grade NdFeB magnet and include a cost comparison of these two magnets with similar magnetic properties. Although attempts have been made to reduce the amount of cobalt in the new magnets, the reviewer questioned if a magnet with significant amounts of cobalt content is the right path to low cost.

Reviewer 6:

The reviewer stated that the magnet has been significantly improved over the course of the program, but still falls short on performance for automotive traction applications.

Reviewer 7:

The reviewer remarked that there has been improvement in coercivity by about 25%, but this is still far away from reaching a level that can enable competitive motor designs

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found active engagement and contributions by project partners including Oak Ridge National Laboratory (ORNL), Arnold Magnetics, and the University of Nebraska. Additionally, collaborators include Ford, UQM, GE, National Renewable Energy Laboratory (NREL), University of Wisconsin – Madison, Baldor, and Carpenter Powder Products.

Reviewer 2:

The reviewer pointed out that collaboration with team members seems to be going well, and there has been collaboration with Arnold and Carpenter on the processing and materials side. There has been collaboration with industry in defining targets and geometry for motor implementation.

Reviewer 3:

The reviewer said that the project has a highly collaborative and diverse team.

Reviewer 4:

The reviewer indicated that this project has many collaborators and partners, some of them from industry, which is very good. However, the crucial question is whether the collaboration with both GE and UQM, which this reviewer emphasized was started in 2012, will lead to any AlNiCo magnet motor designs that show any promise as a traction motor.

Reviewer 5:

The reviewer said that the lack of a real motor that meets an OEM requirements would have strengthened the argument that AlNiCo can meet the needs of an automotive application.

Reviewer 6:

The reviewer noted that there are a large number of collaborators and it is not clear the level of involvement of each of them.

Reviewer 7:

The reviewer reported that the project team consists of Ames Laboratory, NREL, ORNL, industries, and two universities. However, from project report and oral presentation, it is not clear what the roles and responsibilities of various team members and collaborators are.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
According to the reviewer, the PI has identified impactful tasks under the Future Research section of the project report.

Reviewer 2:
The reviewer noted that the remaining fiscal year (FY) 2018 tasks include developing focused theory and simulation, synthesizing test samples, and characterizing them. Suggested FY 2019 follow-on to this project (work scheduled to end in September 2018) would be to promote team interactions, develop additional focused theory and simulation, perform characterization, and synthesize additional test samples.

Reviewer 3:
The reviewer commented that future research seems focused on further gradual improvement of the new materials. It does not appear as if there are any major breakthroughs expected.

Reviewer 4:
The reviewer said that there is limited future work as the project ends by the fourth quarter of FY 2018. The follow-up motor work planned at ORNL is not formally outlined.

Reviewer 5:
The reviewer stated that there are proposed tasks for further improving coercivity, but it was not clear that there is a path for doubling the coercivity or achieving significantly higher coercivity than the achieved 2,500 Oe.

Reviewer 6:
The reviewer stated that in terms of what is needed to achieve the next goal of improving Br, there seems to be a well-defined plan and good understanding of what is needed. It was a little unclear to the reviewer in terms of what the plan was for demonstration in a final product.

Reviewer 7:
The reviewer was concerned that the project will not have anything usable by industry for EV traction motor applications.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer remarked that in general, the development of new magnet materials is relevant to meet the DOE 2025 targets.

Reviewer 2:
The reviewer stated that development of RE-free PMs for electric drive motors directly supports DOE goals of improving vehicle fuel efficiency (electric drive versus internal combustion engine) and domestic energy security (reduced reliance on imported petroleum and RE metals).

Reviewer 3:
The reviewer said that if higher coercivity AlNiCo can be achieved, it can enable RE-free motor designs, which is consistent with DOE’s vision

Reviewer 4:

The reviewer stated that the project was supportive of DOE objectives when it was initiated. However, it has fallen short of competitive technologies that will support DOE objectives while meeting OEM traction application requirements.

Reviewer 5:

The reviewer said yes, for cost because the development of the improved AlNiCo material could help address the Vehicle Technologies Office (VTO) targets in terms of cost; however, it depends on the relative demand and stability of cobalt elements versus RE elements. It is difficult to predict which elements will be costlier and more difficult to procure in the future; even so it represents a good hedge to any rise in RE element prices.

The reviewer said, no, for power density because the targets set for the AlNiCo magnetic properties make it relatively comparable to NdFeB- based motors in terms of power density today if used in an appropriate motor topology. Other improvements beyond the improved properties of AlNiCo will be needed to meet the new aggressive targets for power density for 2025.

Reviewer 6:

The reviewer pointed out that power-dense, low-cost, high-performance electric machines are required to meet 2025 cost and power density targets outlined by DOE VTO. This project somewhat addresses these objectives, except there is no clarity about adoption and large-scale commercialization.

Reviewer 7:

The reviewer stated that the project has the best of intentions, but market changes/realities need to be considered.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that funding is sufficient.

Reviewer 2:

The reviewer believed that Ames has sufficient resources to complete the work on the magnet.

Reviewer 3:

The reviewer commented that resources are sufficient based on the proposed scope.

Reviewer 4:

The reviewer noted that the PI has sufficient resources and the PI’s plan to interact with collaborators will further streamline and put in place resources needed in successful execution of this project

Reviewer 5:

The reviewer said that resources are sufficient. Highly qualified people are assigned to the project.

Reviewer 6:

The reviewer stated that the materials researchers at Ames and associated partners have excellent knowledge and experience for executing this type of research and development and seem positioned for completion of goals. Due to the change in DOE targets, a reassessment of the goals of this program and how it will address design requirements at the motor level may be needed. The resources for doing this also appear to be in place with Ford and other industry members.

Reviewer 7:

The reviewer remarked that this project received $1.4 million in FY 2017 and $700,000 in FY 2018 funding. The FY 2018 funding level has reduced the number of project team members, which has likely affected the potential technical achievements. The DOE Technology Commercialization Fund project was mentioned as a complimentary pathway for net-shape AlNiCo magnets commercialization with suppliers and OEMs.

Presentation Number: elt049
Presentation Title: Advanced High-Performance Computing (HPC) Multiphysics Modeling of Motors and Materials
Principal Investigator: Jason Pries (Oak Ridge National Laboratory)

Presenter
Jason Pries, Oak Ridge National Laboratory

Reviewer Sample Size
A total of six reviewers evaluated this project.

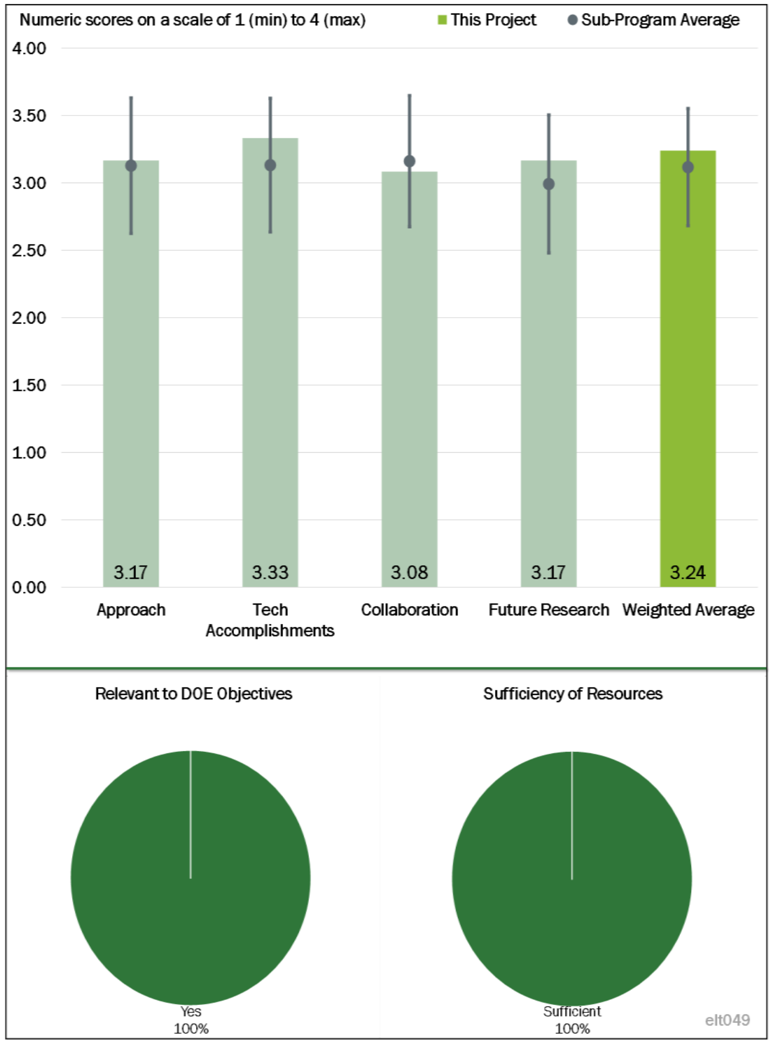

Figure 4-2 - Presentation Number: elt049 Presentation Title: Advanced High-Performance Computing (HPC) Multiphysics Modeling of Motors and Materials Principal Investigator: Jason Pries (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer stated that the goal is to develop a high-performance computing (HPC) tool for electric motor design. The focus on multiphysics interaction is excellent, and the goal to develop open-source software will help to accelerate technology development to meet the DOE 2025 goals for electric motors.

Reviewer 2:
The reviewer observed a very good approach with taking advantage of HPC to overcome the challenging task to connect microscopic level of magnetic behavior to macroscopic level of electric machine behavior. Also, the reviewer highly appreciated making it accessible to the public by making it open-source. A possible consideration for the target model error of less than 5% is verifying the hardware measurement method as the baseline for validation of computational results.

Reviewer 3:
The reviewer stated that simulation tools are an important contribution to the advancement of magnetic materials. The tools will leverage the HPC capability at ORNL and other DOE laboratories. By making the software open source, many other people around the world will be able to contribute to the code, make improvements, and enable other magnetics researchers to develop new materials more easily.

Reviewer 4:
The reviewer said that the approach of high-fidelity modeling with great correlation and increased throughput would be a welcome addition to the tool boxes of all electromagnet (EM) designers. Metrics of less than 5% error (without tweaking) and 10 times the throughput improvement seem aggressive but are a welcome goal.

Reviewer 5:
The reviewer suggested that it may be better to compare the proposed method with the baseline or commercial software to demonstrate the advantage of the modeling method being explored, and set up criteria/projected performance goal for the success of modeling.

Reviewer 6:
The reviewer commented that the objectives for which the computational model needs to represent all nonlinearities and spatial features of the magnetic material are very ambitious. However, the presented slides do not sufficiently support the claims. The reviewer was seriously concerned about the demagnetization due to heat and its dependency on time (multiple runs result in more decay of magnetic quality), which is left vague here. Frequency dependency of the core losses are briefly mentioned without much elaboration on how it will be taken into account.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said that the project is in its first year. With that in mind, the accomplishments and progress are excellent.

Reviewer 2:
The reviewer observed good progress.

Reviewer 3:
The reviewer asserted that the progress looks good. The new software matches commercially available software well and, in some cases, eliminates some errors found in the commercial software.

Reviewer 4:
The reviewer remarked that very encouraging accomplishments were presented. The reviewer suggested also looking into the soft-magnetic material's magnetic-flux density (B) versus magnetic-field strength (H) (B-H) minor-loop validation with hardware measurements and frequency limit.

Reviewer 5:
The reviewer pronounced that it is early in the program and the scheduled goals milestones, while met, have not been challenging yet.

Reviewer 6:
The reviewer referenced prior comments. The reviewer stated that, also, there is an ambiguity in the 2018 funding start date of the project, which does not match the date of publication in the proceedings of the Energy Conversion Congress and Exposition (ECCE) 2017.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer described technical accomplishments and progress as excellent.

Reviewer 2:
The reviewer stated that the team is working with Ames Laboratory for data on hard magnetic materials and with NREL for thermal management research.

Reviewer 3:
The reviewer remarked that the list of collaborators seems to be sufficient and reasonable to advance this project.

Reviewer 4:
The reviewer commented that there was not a lot of collaboration evident yet nor valuable contributions. However, the reviewer noted that it was early in the project.

Reviewer 5:
The reviewer stated that collaboration with two other national laboratories has been established. It would be beneficial if some guidance or input from industry is included.

Reviewer 6:
According to the reviewer, there is good collaboration in magnetic material science with Ames Laboratory and in thermal modeling with NREL. It might be also good to obtain inputs from industry about motor design aspect.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
According to the reviewer, the team appears to have a good plan in place.

Reviewer 2:
The reviewer commented each goal, challenge, solution, and impact are identified in a straight-forward, linear fashion.

Reviewer 3:
The reviewer remarked that validation of the modeling assumes confident-enough hardware measurement results as the baseline. It would be better to have a plan for hardware-measurement confidence level improvement as well.

Reviewer 4:
The reviewer stated that the proposed future work for 2018 and 2019 seems to focus on the modeling of permanent magnet demagnetization and core-loss estimation. There is no mention of extending the nonlinear geometric constraint solver to motor types other than synchronous reluctance motors. If it is not already in the future plans, the reviewer suggested that permanent magnet type motors should be included in this part of the project.

Reviewer 5:
The reviewer noted that there is a need to mention the issues for the new model to address and how.

Reviewer 6:
The reviewer commented that the timeline indicates that the project extends to 2020. However, the research goals to be achieved in 2020 were missing.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented that the improvement of electric motor design and optimization tools is essential for meeting the DOE 2025 goals.

Reviewer 2:
The reviewer remarked that electromagnetic behavior understanding and prediction are critical to meeting DOE objectives.

Reviewer 3:
The reviewer noted that this project is developing a multi-physics computing/modeling method to support electric motor designs, optimization, and virtual prototyping.

Reviewer 4:
The reviewer said that this project will allow for more detailed exploration of magnetic materials, allowing for further optimization and increased speed of new developments.

Reviewer 5:
The reviewer said that the objectives outlined here match well with the priorities of DOE.

Reviewer 6:
The reviewer stated that effective use of modeling and simulation gives the design teams the tools needed to experiment quickly and inexpensively on solutions to meet DOE Program goals

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer found the resources to be sufficient.

Reviewer 2:
The reviewer indicated that the provided funds seem to be sufficient to support the project's objectives.

Reviewer 3:
The reviewer had no concerns about the resources and stated that the project seems staffed at the correct levels

Reviewer 4:
The reviewer noted that the resources look sufficient in the modeling and HPC aspect. However, if there is a shortage for the model validation with hardware measurements, specific planning should be made with looking at further steps to take.

Reviewer 5:
The reviewer found it difficult to comment on the resources because the total project funding was not provided in the AMR presentation. The funding for 2018 only, $648,000, seems more than sufficient, considering there has not been any hardware development so far.

Presentation Number: elt054
Presentation Title: Drivetrain Performance Improvements Techniques
Principal Investigator: Gui-Jia Su (Oak Ridge National Laboratory)

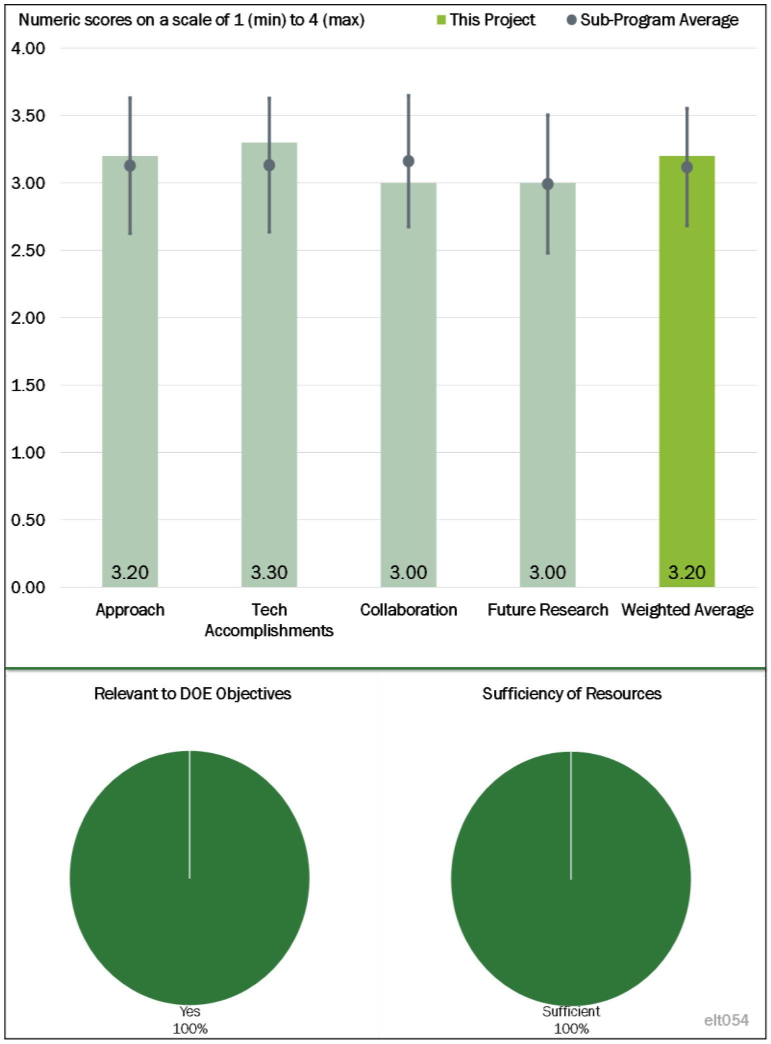

Figure 4-3 - Presentation Number: elt054 Presentation Title: Drivetrain Performance Improvements Techniques Principal Investigator: Gui-Jia Su (Oak Ridge National Laboratory)

Presenter
Gui-Jia Su, Oak Ridge National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
According to the reviewer, the approach is logical and systematic to build the platform, simulate/review, build validation, and validate.

Reviewer 2:
The reviewer commented that the approach is well thought out to identify the best possible switch scheme, derive the equations, simulate and compare results to today's switch schemes, and then test and validate with actual hardware. For both the simulated and actual hardware, the reviewer inquired if the project team could compare efficiency gains over a drive cycle or cycles as opposed to steady state. For this switch scheme, the reviewer asked what the effects are on the ripple voltage that the direct current (DC) link capacitor would see.

Reviewer 3:
The reviewer thought that the basic approach was sound, but assumes that the BMW and Camry loss maps are accurate and include a complete strategy of loss optimization. Complex control strategies (Six-Step, discontinuous pulse-width modulation, and reduced switching frequency based upon load and speed) may not be accounted for in the published loss maps.

Reviewer 4:
To the reviewer, this approach appears to be a promising method of reducing power loss in inverters. The reviewer expressed concern that the control algorithm will be difficult, though not impossible, to implement, especially when dealing with transients.

Reviewer 5:
The approach seemed promising to the reviewer. However, the assumptions made throughout the project are of some concern to this reviewer: Using averaging and linearization (neglecting the nonlinear behavior of the switching circuit), assuming only sinusoidal waveforms, and analysis of the power loss only for the steady-state regime while a good portion of losses occur during the transient. Furthermore, the clarity of the modulation technique needs some more work.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that the team has made good progress on modeling the control algorithm and inverter losses, as well as communicating with device manufacturers to understand the different loss mechanisms.

Reviewer 2:
Considering the simplifying assumptions, the reviewer remarked that the progress made thus far is good.

Reviewer 3:
The reviewer said that the project is on track; the simulated data look encouraging.

Reviewer 4:
The reviewer pronounced that work as good, thorough analytical work to this point and shows promise in theory.

Reviewer 5:
The reviewer stated that this is a relatively new project and progress is limited at this date.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer noted that the team has partnered with Wolfspeed and Rohm for better understanding the loss mechanisms in SiC power devices and with NREL on thermal management research.

Reviewer 2:
The reviewer found the project to be lacking basic benchmarking of loss optimization strategies currently being employed by OEMs. The reviewer suggested that patent searches and Institute of Electrical and Electronics Engineers (IEEE) paper searches may provide more information for setting goals and enhance project work.

Reviewer 3:
The reviewer commented that the collaboration part and the collaborators' tasks are not quite clear.

Reviewer 4:
According to the reviewer, partners are providing loss data for the switching devices; they do not appear to be actively involved with the program details.

Reviewer 5:
At this point in the project (early), the reviewer noted that the engagement and coordination with other institutions seems sparse. There are primarily discussions with SiC power module suppliers and seemingly no collaboration with NREL yet. Then, it is not clear what NREL's tasks and deliverables will be.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that implementation of some of the proposed switching strategies will likely have implications on the vehicle (noise, vibration, and harshness of the traction motor is one example).

Reviewer 2:
The reviewer said that the team appears to have a good plan in place.

Reviewer 3:
The reviewer noted that the items listed for the future research show that the authors are well aware of the limitations and the path forward to address some of the challenges.

Reviewer 4:
The reviewer indicated that the project is well-planned, but alternate pathways are not mentioned. The project team will not know for certain if there is a problem until the team compares simulated results to actual results at the end of the program.

Reviewer 5:
The reviewer found the future work plan to be logical with appropriate decision points. However, the reviewer did not see barriers adequately discussed and/or mitigation for them.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that reduced losses through control strategies (improved efficiency) may allow for less battery and improved range for electric traction applications.

Reviewer 2:
The reviewer said that this project aims to reduce the thermal load from inverters, which could allow for higher power density and/or reduced thermal management requirements.

Reviewer 3:
The reviewer remarked that increasing efficiency at low speeds for the given range of torque is an important issue to be addressed.

Reviewer 4:
The reviewer observed that this approach improves efficiency and improves vehicle range, with little or no added cost to the vehicle. It also enables lower greenhouse gases, lowers dependence on foreign oil, and helps to enable the marketplace for electric drive vehicles (EDVs).

Reviewer 5:
The reviewer commented that an improvement in drive unit light-load efficiency pays dividends towards DOE goals, i.e., less consumed electrical power during lengthy times of drive cycle; less thermal management needed,

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

According to the reviewer, this is just the start of the project, and the provided resources seem to be sufficient to support the execution of the project.

Reviewer 2:

The reviewer stated that resources appear sufficient and available.

Reviewer 3:

The reviewer noted that this small project is fully staffed and has adequate resources.

Reviewer 4:

The reviewer believed that there are sufficient resources to complete the project. OEM collaboration and/or benchmarking would provide more insight on this project.

Reviewer 5:

Resources appear to be sufficient for the given scope of the project, according to the reviewer. However, for deployment into the field, the reviewer suspected that a follow-on project will be needed for rigorously testing the control algorithm.

Presentation Number: elt071
Presentation Title: Ultraconducting Copper
Principal Investigator: Tolga Aytug (Oak Ridge National Laboratory)

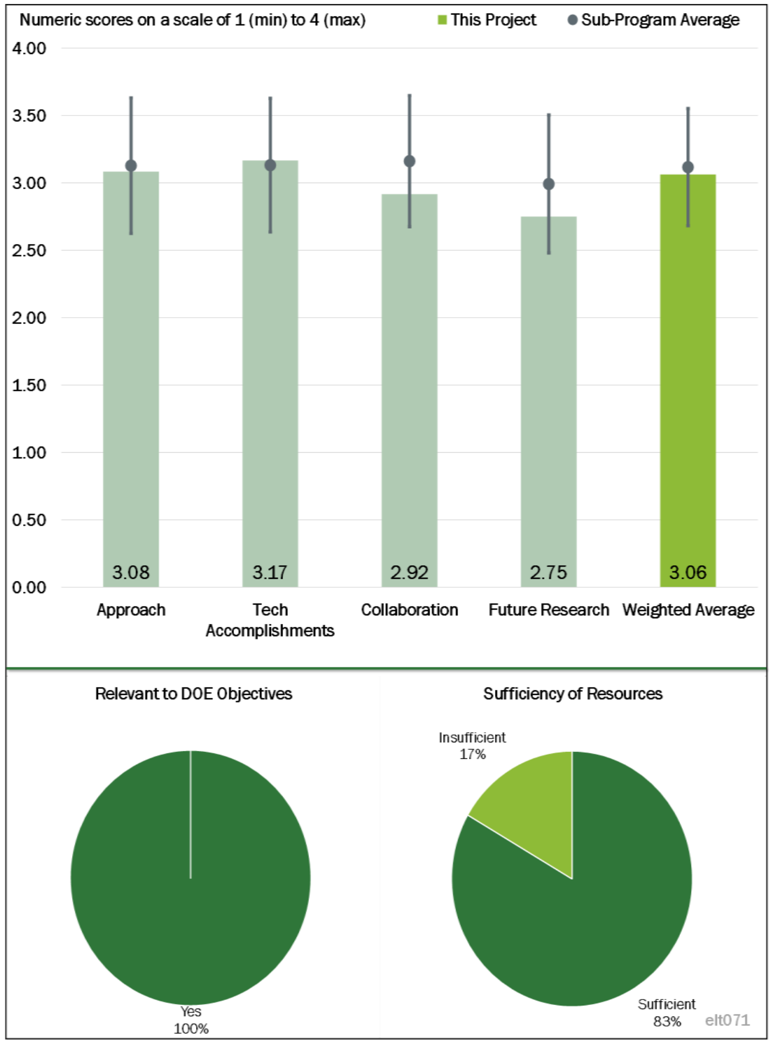

Figure 4-4 - Presentation Number: elt071 Presentation Title: Ultraconducting Copper Principal Investigator: Tolga Aytug (Oak Ridge National Laboratory)

Presenter

Tolga Aytug, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer pronounced the approach in terms of the area or research to be excellent. Copper is the source of loss and directly going after reduction of loss at the materials level makes sense. The theoretical potential of copper-carbon nanotubes (CNT) materials is impressive and therefore it should be developed. The reviewer commented that the approach is rightly focused on optimizing the production of the materials to maximize the improvements in performance.

Reviewer 2:

The reviewer stated that improved and high-performance conductors for electric machines and inverter interconnects are needed. This project supports DOE VTO 2025 targets for electric drive system needed for EVs, HEVs, PHEVs, etc.

Reviewer 3:

The reviewer said" the approach is well thought-out."

Reviewer 4:

The reviewer stated that the objective is to develop high-performance copper material using CNT resulting in higher electrical and thermal conductivity. The main focus so far has been on the basic material development, e.g., the multilayer architecture with copper film and CNT layers. This has to continue in the second half of the project, but additionally the reviewer suggested that the focus should extend more to how this new material can actually be used in a manufacturable electric machine. The reviewer questioned if a tape or foil winding is the right approach for a high-power traction motor.

Reviewer 5:
The reviewer thought that the baseline approach is sound as it relates to the science of copper deposition on CNT. The reviewer expressed concern regarding the eventual implementation of copper tape in the manufacturing of a motor. The reviewer would like to have seen more thought given to how this technology would eventually be implemented in conventional motor manufacturing.

Reviewer 6:
The reviewer noted that there are several organizations pursuing copper-CNT conductors. It is important to explain how this effort is different and how the proposed approach will lead to advantages in terms of manufacturing and/or properties.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer stated that the project team has developed a method to realize copper-CNT and has carried out experiments to measure electrical characteristics of copper-CNT.

Reviewer 2:
Given the amount of resources on this project, the reviewer indicated that excellent progress has been made.

Reviewer 3:
The reviewer pointed out that there has been significant progress in the development of the processing techniques for CNT deposition on copper tapes. However, the reviewer commented that the accomplishments with regard to materials property improvements compared to conventional copper are not very encouraging yet because the prototype samples show only a decreased resistivity of 5%-8%. The reviewer suggested that this has to decrease by a much larger extent in order to make this a viable solution for electric machines (tradeoff of increased cost versus decreased copper losses).

Reviewer 4:
The reviewer commented that the technical assessment stating reduction of copper mass in the motor is merely an electromagnetic design exercise. It does not consider how to manage insulation and interconnection technology using the CNT-copper tape. It merely takes advantage of the improved conductivity.

Reviewer 5:
The reviewer said that good progress has been made and the fact is that several samples have been tested. The 5%-8% reduction in resistivity shown so far seems fairly low for what is theoretically expected for a copper/CNT conductor and is not transformational. The reviewer proposed that more significant reduction in resistivity should be accomplished to ultimately justify this effort. Also, the reviewer believed that all the results presented were based on DC measurements. Because these conductors are intended for traction motors, which are typically high-frequency, investigation of alternating current (AC) losses in the copper/CNT conductor should be performed.

Reviewer 6:
The reviewer pronounced the initial improvement in electrical conductivity/resistivity over copper (5%-8% improvement over copper) to be a good start. The reviewer posited that it is obviously a long way from the theoretical value of 1.7, which may be approached but possibly not met due to the need for perfect conditions. Progress in thermal conductivity improvements was unclear to the reviewer. The process was also down-selected from three processes to two.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviews stated that collaboration is excellent due to the inclusion of several industry partners in the project.

Reviewer 2:
The reviewer noted that the DOE-ORNL led project team consists of multiple industries and DOE-NREL.

Reviewer 3:
The reviewer wanted to see more collaboration with production wire manufacturers as the reviewer did not believe that this technology will be well-executed if it cannot be implemented in motor grade wire.

Reviewer 4:
The reviewer remarked that most of the work is done within ORNL. More quantification of the motor performance benefits potentially working with OEMs is encouraged.

Reviewer 5:
The reviewer noted the collaboration with NREL and found it appropriate due to the close relevance of utilizing thermal management for further improving this idea. The reviewer indicated that there was also some industry input; more benefit may be achieved from multiple industry partners to guide development targeted at commercialization.

Reviewer 6:
The reviewer suggested that this project needs an industrial partner to be successful.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer mentioned that the project team plans to keep improving materials and processes required to realize high-performance copper-CNT.

Reviewer 2:
The reviewer stated that the proposed future work is good from a technical perspective. But at some point, the reviewer said that the team has to provide an estimate of the cost impact. The tradeoff between increased cost and the expected performance benefit is crucial for this project.

Reviewer 3:
The reviewer remarked that ultra-conducting copper (UCC) is a great objective towards meeting 2025 DOE goals; however, the project needs a more realistic approach to implementation in production. Also, there needs to be a better understanding of the cost impact.

Reviewer 4:
The reviewer stated that it is important to target higher reduction of resistivity. It is important to investigate AC losses.

Reviewer 5:
The reviewer indicated that the future work focuses appropriately on optimizing processes to improve materials properties. The reviewer pointed out that there could have been more specific detail on how optimization will be explored and down-selected to one process. Also, the project did not provide targets for

electrical and thermal conductivity beyond the theoretical values of the material in the ideal state. Achievable or probable targets for these two parameters would have been helpful. The reviewer also said that plans for implementation in motors and scaled or representative models would be beneficial to this project.

Reviewer 6:
The reviewer suggested that the project team needs to have an industrial partner to understand all aspects that should be studied.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted that the project is relevant as improved materials are needed to meet the DOE 2025 power-density targets in electric machines.

Reviewer 2:
The reviewer stated that low-cost and high-performance copper-CNT could be useful in projects funded by DOE VTO and could strongly support 2025 DOE VTO targets for electric drive systems

Reviewer 3:
The reviewer viewed this work as critical to the success of electric drive and other power electronics applications.

Reviewer 4:
The reviewer observed that copper-CNT conductors can have a significant impact on improving the efficiency and power density of traction motors.

Reviewer 5:
The reviewer believed that this project is very relevant. Motor performance improvement will be difficult, and cost reduction will be even more challenging. While the UCC promises significant improvement in conductivity, it was not clear to the reviewer that it will be cost effective. If the mass savings outweigh the additional cost of the UCC, it will support the DOE objectives.

Reviewer 6:
The reviewer commented that relevance to DOE targets is very high in terms of meeting power density requirements. Even if the project achieves half of the theoretical current density prediction, this will go a long way to meeting objectives. The reviewer posited that cost is the question as always at this stage of development so a qualitative evaluation of material and process cost would be helpful.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer believed that the resources are adequate.

Reviewer 2:
The reviewer indicated that the allocated budget is sufficient for the proposed scope.

Reviewer 3:
The reviewer commented that the funding of $300,000 per fiscal year is potentially on the low end for a project that involves manufacturing hardware samples, especially considering the complicated processing techniques.

Reviewer 4:
The reviewer suggested that more industry partners may be helpful in terms of guiding development for eventual implementation.

Reviewer 5:

The reviewer asserted that the project team should explore more applications of copper-CNT beyond its use in motors. This could require the PI to approach industries and academic institutes willing to provide application platforms for copper-CNTs, which would put application-specific resources at the disposal of the PI.

Reviewer 6:

According to the reviewer, significant resources need to be added to this project for it to contribute towards program objectives. This work has implications across the board.

Presentation Number: elt074
Presentation Title: Non-Rare Earth Electric Motors
Principal Investigator: Tsarafidy Raminosoa (Oak Ridge National Laboratory)

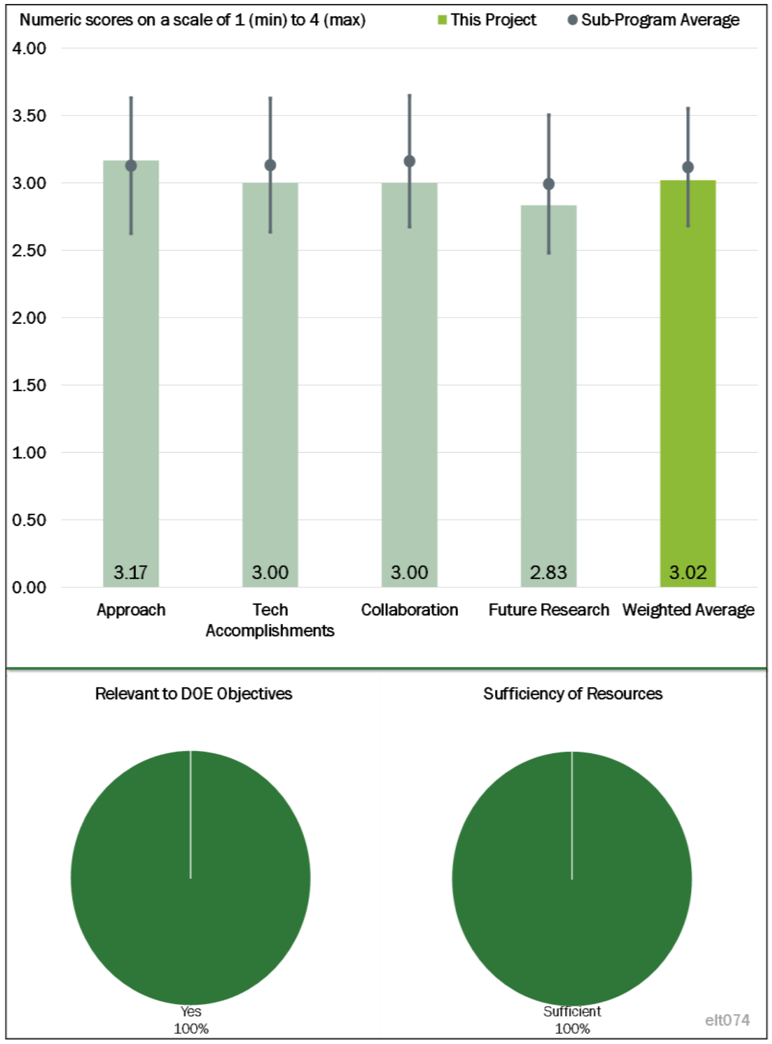

Figure 4-5 - Presentation Number: elt074 Presentation Title: Non-Rare Earth Electric Motors Principal Investigator: Tsarafidy Raminosoa (Oak Ridge National Laboratory)

Presenter

Tsarafidy Raminosoa, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that it would have nice to describe why rotary transformer excitation was chosen as the wound-rotor excitation method.

Reviewer 2:

The reviewer described the approach involving the development of a rotating transformer as a delivery mechanism for field current to a wound-field synchronous machine (WFSM). The approach also involves utilization of copper-CNT material development from another program to downsize/increase power density to the target of 50 kilowatt per liter (kW/l). In addition, a parallel effort involves design of an AlNiCo magnet-based motor using enhanced AlNiCo material from Ames. The reviewer stated that the rotating transformer may increase reliability for WFSMs by eliminating the wear elements in the commonly used slip rings for this type of machine. However, it is unclear to the reviewer how the rotating transformer will help meet cost and power-density goals. Copper-CNT material seems to be the primary approach for helping WFSM architecture to meet power density and cost goals. It is also unclear to the reviewer how the AlNiCo motor will help meet power-density goals given that the target magnetic properties are not better than state-of-the-art NdFeB motors that currently are not meeting power density goals of 50 kW/L. Though AlNiCo may help meet cost targets, only if cobalt (Co) prices decrease with respect to NdFeB, it did not seem to the reviewer that the elements of this project can be combined to collectively provide cost, reliability, and power-density targets; however, each individually could help meet components of the targets. The reviewer stated transformer-reliability, AlNiCo-cost, and Cu-CNT in WFSM equals power density.

Reviewer 3:

This reviewer stated not applicable.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer questioned the rotary transformer design by asking how the design verification with hardware test will be carried out. The reviewer also wanted to know whether, for ultra-conducting copper, both the baseline copper foil wound machine and the ultra-conducting copper foil machine would be constructed and tested for side-by-side comparison.

Reviewer 2:
The reviewer remarked that the go/no-go decision for transformer plus WFSM meeting power-density targets seems unlikely due to a predicted size/weight reduction of only 6%-7% based on copper-CNT material.

Reviewer 3:
This reviewer stated not applicable.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that NREL, Ames, and ORNL have excellent people and capabilities to perform the work required. No industry partner was noted but one may be helpful in providing commercialization expertise.

Reviewer 2:
The reviewer found the collaboration with other national laboratories to be good. The reviewer noticed that no industry partner is stated and suggested that it might be a good idea to have industry inputs during this activity.

Reviewer 3:
This reviewer stated not applicable.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
It was unclear to the reviewer if the team will build and test both the AlNiCo motor and WFSM motors or just simulate. Otherwise, the future plans seemed good in terms of demonstrating the concepts.

Reviewer 2:
The reviewer asked about whether the compensation capacitors need special precision. If yes, then the reviewer wanted to know how that would affect the cost. The reviewer inquired about whether the compensation capacitors' long-term characteristics degradation would affect the rotary transformers' power transfer performance. If yes, then the reviewer asked whether that would be quantified. The reviewer questioned how one can compare the rotary transformer power transfer and the capacitive power transfer discussed in project ELT092. The reviewer appreciated hearing discussions of pros and cons. The reviewer wanted to know if a permanent magnet machine with AlNiCo also would be prototyped and tested with high-temperature.

Reviewer 3:
Set up criteria/projected performance goal for success was indicated by this reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer responded, yes.

Reviewer 2:

The reviewer remarked that both the alternative permanent magnet (AlNiCo) and the wound-rotor machine are potential candidates for alternatives to existing, heavy rare-earth permanent magnet machines.

Reviewer 3:

Although all of the elements of the project have some relevance to the 2025 goals, it was difficult for the reviewer to see how any one of them or a combination of them could allow the goals to be met. It purely depends on the development progress of copper-CNT, where so far, a 6%-7% size reduction has been attained, significantly more is needed.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

It appeared to the reviewer that the resources are appropriate to execute the scope.

Reviewer 2:

Currently, resources looked sufficient to this reviewer. However, it was not quite clear at this point for the reviewer that wound-rotor machines with both conventional copper and ultra-conducting copper and also AlNiCo permanent magnets (three prototype machines in all) will be constructed for hardware testing.

Reviewer 3:

This reviewer stated not applicable.

Presentation Number: elt075
Presentation Title: Electric Motor Thermal Management
Principal Investigator: Kevin Bennion (National Renewable Energy Laboratory)

Presenter

Kevin Bennion, National Renewable Energy Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the approach is good, the steps are logical, and the project is certainly feasible.

Reviewer 2:

The reviewer agreed with the approach to focus on the thermal interfaces; these are tough problems to solve.

Reviewer 3:

The reviewer stated that new and advanced materials are needed for aggressive heat-transfer required in power-dense electric machines. The project team has identified materials and has carried out thermal characterization.

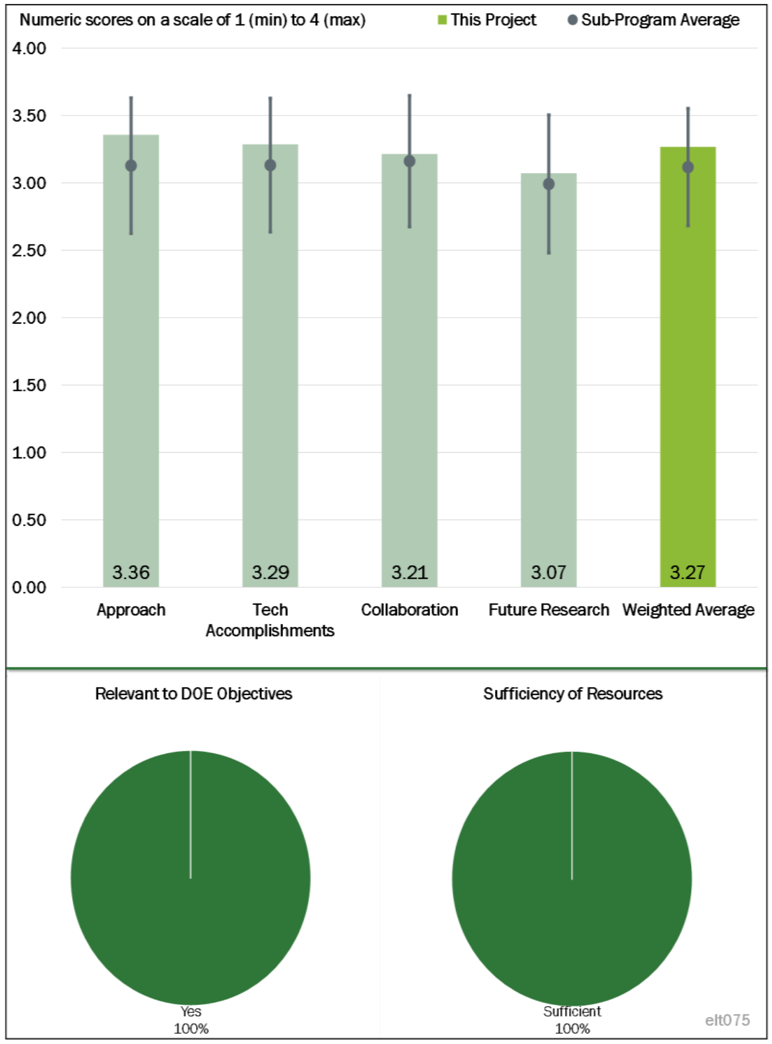

Figure 4-6 - Presentation Number: elt075 Presentation Title: Electric Motor Thermal Management Principal Investigator: Kevin Bennion (National Renewable Energy Laboratory)

Reviewer 4:

The reviewer pointed out that the key technical barriers to increasing motor power density and lifetime while reducing cost are related to materials and modeling. The thermal conductivity of the base metals, the epoxies and fillers, and especially the windings drive the amount of material needed to create the required magnetic field. The reviewer stated that higher electrical and thermal conductivity windings, for example, would mean smaller wires and thus significantly reduced cost, size, and weight.

The reviewer observed that one element of this project focuses on developing material performance characterization techniques, an area not currently well-covered in the literature, in order to gain the accurate material parameters needed to speed up design (e.g., fewer iterations). These techniques, according to the reviewer, will also permit the insertion of new materials to reduce the thermal resistance of the motor, thereby increasing the power density. The approach to addressing these issues is well-designed and focuses on thermal interface resistance, an area equal in importance but less well studied than bulk conductivity owing to the difficulty in measuring it. Thermal interface resistances at the stator-to-case, line-to-stator, winding-to-liner, and cross-slot winding are assessed.

The reviewer asserted that another element focuses on the development of active motor cooling technologies to take advantage of the new motor materials. These include various forms of jet impingement and direct cooling with a variety of fluids, including automatic transmission fluid (ATF). This is also well-designed, looking at the effect of a variety of impingement parameters including incidence angle, distance from target, and fluid temperature.

Reviewer 5:

The reviewer noted that the objective of this project is materials and interface thermal characterization and evaluation of motor systems impact with active cooling. The reviewer found the measurement of lamination thermal contact resistance to be of value. For the winding thermal characterization, the focus has been on stranded winding although the industry is mainly switching to bar winding for traction motors. The reviewer suggested that it would be good if the project could be extended to cover this type of winding.

Reviewer 6:

The reviewer pronounced the project approach to be good in terms of quantifying many factors that can impact the design/prediction of the motor's thermal management system. In order to achieve a 10-fold improvement in power density, very novel thermal management schemes need to be proposed/developed. So far, the reviewer said that the project has been focused on quantifying existing materials and thermal management techniques.

Reviewer 7:

The reviewer indicated that the approach involves improving key parameters for motor thermal modeling as well as evaluating new thermal approaches for improved performance. Both are needed to meet targets. According to the reviewer, this area of work will be key in meeting the new targets. It would be good to see some other approaches to improve thermal performance beyond impingement of oil and proposed design of experiments to evaluate.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that there was excellent progress reported, including publications in the technical literature.

Reviewer 2:

According to the reviewer, the team at NREL has successfully characterized many motor thermal impedance areas that have eluded motor designers (contact resistances of various materials). This work will benefit industry greatly and forms the basis for making improvements from industry standards.

Reviewer 3:

The reviewer stated that certainly having the motorettes in the future will enable validation of the technical accomplishments and progress.

Reviewer 4:

The reviewer mentioned that significant progress has been made in the first year of this program in the development of methods and models for the measurement of cross-slot winding thermal resistance, stator lamination thermal resistance, and stator-to-case thermal resistance. In addition, the thermal and mechanical properties of magnet materials were measured. The reviewer stated that these values were then used to determine the thermal resistance of a series of slot windings, those windings when bonded to a slot liner, and the slot liner when coupled into a segment of the stator. Furthermore, progress was made on quantifying the effect of key parameters on heat transfer in orifice jet impingement, fan jet impingement, and direct cooling with ATF. This work showed increases in heat transfer coefficient with surface temperature and nozzle jet velocity, according to the reviewer.

Reviewer 5:

The reviewer acknowledged that the project is progressing according to plans. The only issue the reviewer had is that the overall work is not challenging the existing knowledge base or progressing it much further. However, they are doing what they said they would do, sticking to the schedule, and publishing their findings.

Reviewer 6:

The reviewer commented that it seems as if a lot of progress has been made, but the actual AMR presentation is very light in content in that regard. Several references to publications have been provided but showed very little results in the presentation. The reviewer did not think that it should be the reviewer's job to find these publications in order to evaluate the progress and accomplishments. The reviewer suggested that this should be improved for next year's AMR.

Reviewer 7:

The reviewer pronounced the progress made to be good, but there is still the big missing piece of quantifying the impact of the more accurate materials/cooling methods on the performance of an actual motor design/prototype. Also, quantification of spray cooling on the insulation life is still another key piece.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

It was apparent to the reviewer that there was excellent bi-directional communication with partners in this project. Collaborators presented problems and NREL analyzed, experimented, and shared results and methods.

Reviewer 2:

The reviewer said that strong, well-coordinated collaborations were exhibited among the internal and external project partners. ORNL was active in the cross-slot windings work and the development of no rare-earth or reduced rare-earth motors. Ames collaborated on the magnetic material properties work. Motor industry suppliers and drive-line fluid suppliers provided fluid properties, insulation material properties, and boundary conditions for simulation and experimental work.

Reviewer 3:

According to the reviewer, there was excellent work across the national laboratories and partners.

Reviewer 4:

The reviewer stated that there was good collaboration with other national laboratories as well as industry.

Reviewer 5:

The reviewer remarked that the NREL-led team has two DOE laboratories and supplier companies for materials required for the motor project. The team and collaboration look adequate to the reviewer.

Reviewer 6:

The reviewer found collaboration with Ames Laboratory to be good and seems adequate. It was not clear to the reviewer what others ("Motor industry representatives") are contributing to the project.

Reviewer 7: 9-40

According to the reviewer, the project PI claims collaboration and coordination with suppliers from motor and fluid industries but provided no company names or details. The reviewer asked what the result has been with these collaborations. Similar to the Accomplishments and Progress section, the AMR presentation does not provide much information and this should be improved next year.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that the proposed work will help quantify the impact of the characterization done so far on a small system resembling a motor.

Reviewer 2:
According to the reviewer, the PI clearly outlined the remaining challenges and barriers in both materials and interface characterization and motor systems active cooling. This included additional reliability work on aging of fluids and materials to support increased lifetime targets; alternative motor designs, including alternative winding configurations, along with methods to improve convective cooling and the use of better fluids. Proposed future research will focus on modeling the "motorette" and material and fluid characterization.

Reviewer 3:
The reviewer asserted that the project team has identified tasks targeted for materials characterization and active cooling of electric motors; these are quite appropriate for successful execution of this project.

Reviewer 4:
The reviewer pointed out that there may be some new developments in the global supply of electric machines in Europe, particularly with the Volkswagen Group's new emphasis that may produce some new thermal management techniques and materials.

Reviewer 5:
The reviewer reported that future planning was good in terms of set up for further experimentation for evaluation of materials and techniques. The reviewer suggested that there may be a need to definitively select new materials for evaluation, develop implementation for the materials, and evaluate more active cooling techniques other than oil-based cooling.

Reviewer 6:
The reviewer found not much content was provided for future research. The one slide shows very general wording and is more or less a copy of a slide under Accomplishments and Progress. The reviewer asked what the specific plan is for future work.

Reviewer 7:
The reviewer stated that the Proposed Future Research looks like business as usual and does not seem to advance the state of the art.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that the project is relevant because the improved understanding of thermal characteristics of electric motors enables better designs.

Reviewer 2:
The reviewer commented that improved thermal management is a key enabler for meeting DOE's motor performance targets.

Reviewer 3:
The reviewer said that this effort has great relevance. The only chance of meeting the new power-density requirements is to make very large improvement in thermal management for both motors and inverters.

Reviewer 4:

As most power systems are thermally limited, the reviewer remarked that research on the passive thermal resistance of materials and the heat transfer potential of active motor cooling schemes with various fluids is critical to achieving the DOE goals of a 10-fold increase in motor power density, two-fold increase in lifetime, and 53% decrease in cost. Better cooling can increase reliability by avoiding failures due to temperature cycling and thermal overstress while improved thermal management can allow the motor to run with less material, thereby reducing cost, size, and weight and increasing power density.

Reviewer 5:

According to the reviewer, higher power and power density will continue to challenge thermal design of machines.

Reviewer 6:

The reviewer commented that advanced cooling for electric machine is a must to accomplish electric drive system's power density target set for DOE VTO.

Reviewer 7:

The reviewer asserted that electric machine cooling is a critical component to efficient and cost-effective electric and hybrid vehicle design and future success. The reviewer would like to have seen the project stretch beyond what may generally already be known and done in industry today.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the resources appear sufficient, considering the cost of building test set-ups.

Reviewer 2:

The reviewer said that resources are sufficient based on proposed scope.

Reviewer 3:

The reviewer indicated that resources seem appropriate and well managed to achieve the stated milestones.

Reviewer 4:

The reviewer found that the project team has the necessary resources.

Reviewer 5:

The reviewer remarked that the project is staffed and funded to hit the scheduled milestones and do so on time.

Reviewer 6:

In terms of research, the reviewer pronounced the resources in the project to be excellent. The program could benefit from more industry partners for consultation and assistance in implementation for the new thermal techniques.

Reviewer 7:

The reviewer was unable to evaluate in detail; the overall magnitude of funding seems reasonable.

Presentation Number: elt077
Presentation Title: Innovative Converters and Chargers
Principal Investigator: Veda Galigekere (Oak Ridge National Laboratory)

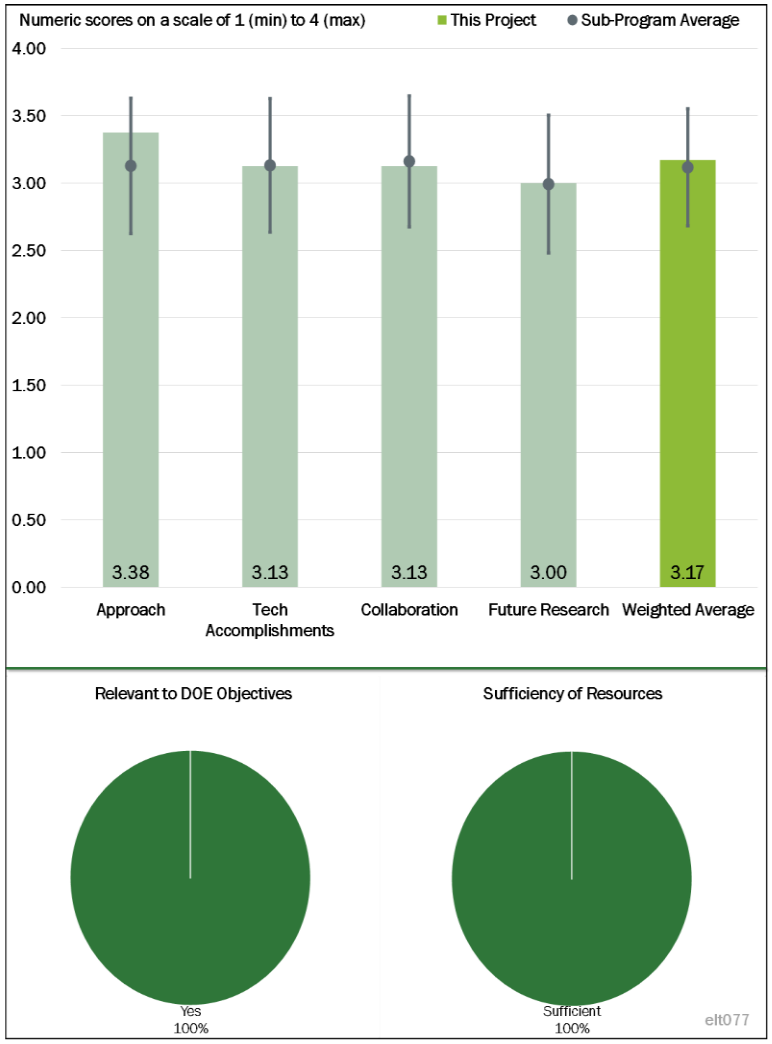

Figure 4-7 - Presentation Number: elt077 Presentation Title: Innovative Converters and Chargers Principal Investigator: Veda Galigekere (Oak Ridge National Laboratory)

Presenter
Veda Galigekere, Oak Ridge National Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer liked the idea of using the traction inverter as part of the wireless power transfer system. The team pointed out one integration issue: increased usage and reduced reliability of the inverter. The reviewer inquired whether there are there other integration barriers, such as increased electromagnetic interference due to high-frequency current in the leads between the coil and the inverter.

Reviewer 2:
The reviewer remarked that addressing increased power density, planar vehicle assembly, and scalability of wireless charger help to lower cost and enable the technology. The project is well designed and feasible.

Reviewer 3:
According to the reviewer, utilizing the existing traction-drive inverter and DC-DC converter for wireless charging are good candidates for a cost-effective realization of wireless charging. The reviewer stated that explicitly itemizing potential issues and roadblocks in implementing such an approach in commercial vehicles from practical viewpoints would have been nice. The reviewer gave parenthetic examples of issues and roadblocks, such as whether any switching-over mechanisms are necessary between the motor and the wireless charge secondary and whether any extra components are needed for the switching over. In addition, the reviewer parenthetically mentioned that the power semiconductor devices chosen for the best performance for the traction inverter may or may not be a good choice for wireless power transfer, in particular if the switching frequency of the traction inverter and that of the wireless charger secondary side are very different.

Reviewer 4:
Not applicable was indicated by this reviewer.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that the team has made good progress on the development of a model and prototype of the proposed system.

Reviewer 2:

The reviewer remarked that the team is focused on their work and appears to be on target.

Reviewer 3:

The reviewer recognized the progress as good, but it looked to the reviewer that the secondary-side hardware is not really a traction-drive inverter connected to the traction motor. The reviewer's understanding is that one of the key points of this project is to integrate with the traction inverter going beyond the laboratory bench. Hence, staying within the proof-of-concept by not using the motor-connected traction-drive inverter could be a value-lessening factor of this project.

Reviewer 4:

This reviewer stated not applicable.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that there is good collaboration with another national laboratory and an industry partner. The reviewer suggested that it would have been nice if the collaboration and coordination were described more specifically about who does what (the slide has more than half empty space).

Reviewer 2:

The reviewer commented that the team is working with NREL on thermal management research and with Lear for project feedback.

Reviewer 3:

The reviewer noted that NREL is shown as a partner, but there is no work in the presentation attributed to NREL at this time. The team from ORNL and Lear appears to be working well. The reviewer stated that it would have been useful for the team to have an OEM representative for the vehicle of choice to help with integration and to help to minimize accessibility issues.

Reviewer 4:

This reviewer stated not applicable.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

According to the reviewer, the team appears to have a good plan in place.

Reviewer 2:

The reviewer found the scalability evaluation of 50 kW to be good, but asked if "evaluate" means hardware prototyping or just a calculation-based estimation. The reviewer requested clarification.

Reviewer 3:

The reviewer stated that the remaining issues need to be addressed as well as how.

Reviewer 4:
The reviewer pointed out that there is no mention about the planar vehicle assembly; otherwise, the proposed future work on scalability and building the wireless fast-charger are logical next steps.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer reported that cost-effective wireless charging for higher power rating is one of the relevant topics.

Reviewer 2:
The reviewer explained that this project has the potential of integrating a wireless power-transfer system with the existing traction inverter, thereby reducing the size and cost of the wireless power system.

Reviewer 3:
Meeting the DOE Electrification Technologies (ELT) 2025 targets on efficiency and increased power density while reducing costs helps to enable EDVs and lower our dependence on foreign oil, according to the reviewer.

Reviewer 4:
This reviewer stated not applicable.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
It looked to the reviewer that the resources are currently sufficient considering the proposed hardware prototyping plan.

Reviewer 2:
The reviewer remarked that the resources appear to be sufficient.

Reviewer 3:
The reviewer pointed out that the project team may need the resources of an OEM to help with integration of their system. Otherwise, the resources are sufficient.

Reviewer 4:
The reviewer said not applicable.

Presentation Number: elt078
Presentation Title: Power Electronics Thermal Management
Principal Investigator: Gilbert Moreno (National Renewable Energy Laboratory)

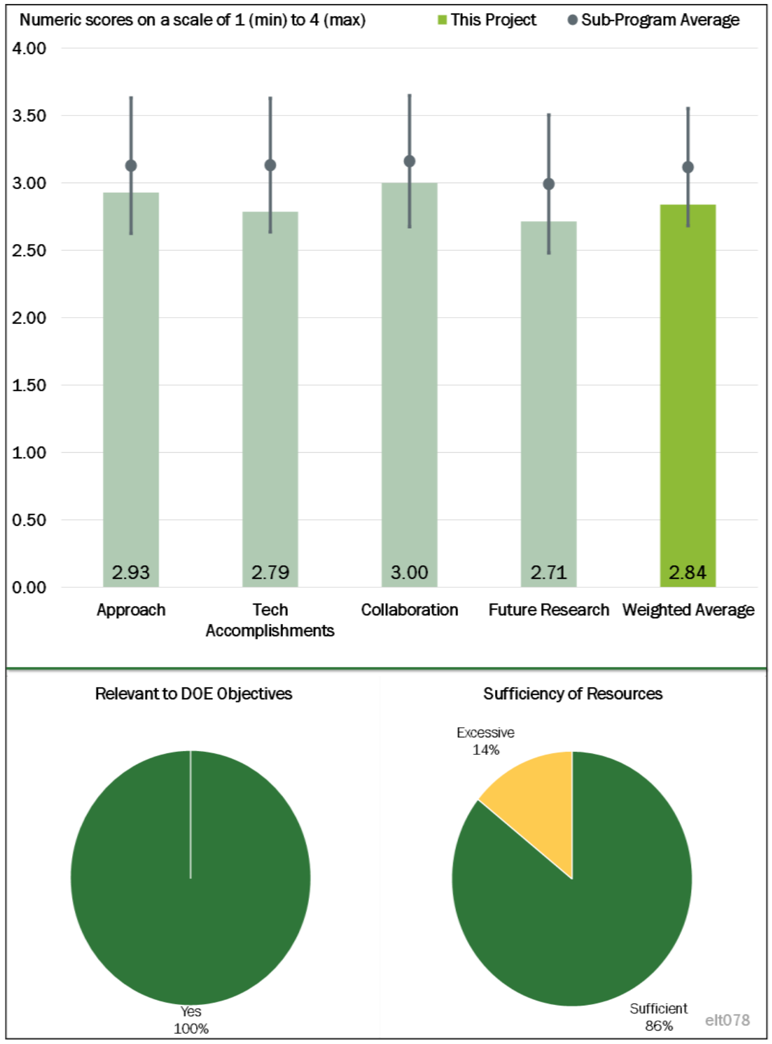

Figure 4-8 - Presentation Number: elt078 Presentation Title: Power Electronics Thermal Management Principal Investigator: Gilbert Moreno (National Renewable Energy Laboratory)

Presenter
Gilbert Moreno, National Renewable Energy Laboratory

Reviewer Sample Size
A total of seven reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer commented that the use of a finned heat spreader significantly improved thermal performance. Using ATF as the device cooling fluid is a good idea to reduce cost in the system.

Reviewer 2:
The reviewer thought that the basic approach is sound, but did not believe that two-phase cooling would be acceptable to automotive OEMs.

Reviewer 3:
The reviewer suggested that fixed assumptions about volume breakdown could be made a little more flexible so that unknown factors can be taken into account. The team could state a few more specific ideas in the approach regarding the potential ATF use.

Reviewer 4:
The reviewer stated that the approach is well designed and clearly feasible as it focuses on making innovative improvements to existing technologies and integrating them to create novel solutions that meet the DOE targets. The study is initially limited to single-phase cooling since, if single phase is sufficient to achieve the needed cooling at reasonable velocities (less than 5 meters per second [m/s]), there is less incentive to move to the more complex two-phase approaches. Also, single-phase systems are easier to seal, thus addressing the sealing challenge. Next, the reviewer noted that the approach evaluates slot jet versus circular jet cooling to address the challenge of low heat transfer for laminar flow of dielectric fluids, finding that slot jets were as good as or better than circular jets at the typical nozzle diameters. However, because neither jet could reach the needed cooling metrics, the reviewer commented that finned surfaces were combined with slot jets to reduce thermal resistance. The reviewer opined that this adds an additional challenge of making sure sufficient fluid is being wicked down the fins. Using lower viscosity dielectric fluid is planned to assist with this. The eventual goal is to move to low-cost ATF to increase efficiency and reduce pumping power, rather than to introduce a

separate system of pumps, reservoirs, and fluid for a separate power-electronics cooling loop. The reviewer remarked that ATF is dielectric, already qualified for automotive use, and permits motor-inverter integration. The team clearly stated the steps to achieve this goal.

Reviewer 5:

The reviewer remarked that the power density target calculation was missing a considerable portion of inverter volume, electromagnetic compatibility filer, bus bars, current sensing, coolant channel volume, connectors, wire harness, and housing. With respect to comparing potential cooling strategies, the reviewer expected a detailed Pugh matrix comparing more than just one aspect of the potential cooling strategy. All that was shown was a comparison of thermal performance. Also, the reviewer stated that there are other cooling strategies that were not considered in the design space. Considering only direct-bonded copper baseplate- and device- cooled was described by this reviewer as a shallow approach.

Reviewer 6:

The reviewer remarked that the feasibility of the proposed approach, i.e., a fluid in the vicinity of all devices, needs more elaboration. Practicality of the method where fluid needs to be pumped through the power electronic devices, while addressing the sealing issue is a concern that requires clear justification.

Reviewer 7:

The reviewer asserted that the inverter model includes gate drives, a control board, a capacitor and power devices. But, there is only a reference to the cooling of the power devices and the capacitor and nothing said about the thermal gradient within the inverter. The reviewer asked about what happens thermally to the gate drives and the control board. The reviewer found the reference to the capacitor volume decrease to be interesting but that reference does not state the value of capacitance or the technology of the capacitor that is reducing in size. Perhaps defining the value of capacitor needed for the inverter would be more appropriate. Once that happens, a capacitor that could survive at 125°Celsius (C) and still fit in the box could be selected. There are automotive-grade components for the control board and gate drive board that will also survive at 125°C. This could help with designing the cooling system. The reviewer asked what the author's assumptions are about the ambient environment around the inverter.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

According to the reviewer, results of the thermal simulations look promising. The approach should enable the system to reach the power density goal.

Reviewer 2:

The reviewer stated that the progress is acceptable based on the project objectives.

Reviewer 3:

The reviewer asserted that it is certainly great accomplishments in dielectric coolant selection, modeling, and thermal design. It would however have been even better, the reviewer opined, if the following were identified: the unknown factors and the critical questions to be answered in eventually using ATF as the coolant because ATF is in the scope of the final coolant selection both in the approach statements and the technical accomplishment statements.

Reviewer 4:

The reviewer mentioned that significant progress has been achieved in the first year of the program toward the 100 kW/l power-density target. This has included conceiving the cooling architecture, developing thermal models for single-phase jet impingement cooling, evaluating slot versus circular jets for a variety of jet parameters (e.g., velocity, nozzle size), and evaluating using finned structures to improve heat transfer. The reviewer noted that additional progress on the cooperative research and development agreement (CRADA) was achieved but not reported on.

Reviewer 5:

The reviewer commented that some proof of concept in theory have been presented, which mainly includes simulation results. However, no experimental results are presented.

Reviewer 6:

The reviewer simply did not see sufficient work products that would equate to the amount of funding in FY 2017 ($493,000).

Reviewer 7:

The reviewer reported that it would have been helpful to see the thermal gradient not only on the power devices but also on the gate drive and the control board. If there is an assumption of 125°C operation capability for the capacitor, gate drive, and control board, then the reviewer asked how that would affect the cooling design.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that the team is working with several organizations to ensure the project progresses in a timely manner and is relevant to the industry.

Reviewer 2:

The reviewer noted that reasonable collaboration and partnership have been reported.

Reviewer 3:

According to the reviewer, the team seems adequate and qualified.

Reviewer 4:

It seemed to the reviewer that collaboration with the team is acceptable.

Reviewer 5:

The reviewer found that there was good collaboration both with another national laboratory and industries. Regarding the above-mentioned ATF questions also, such collaboration could be made.

Reviewer 6:

The reviewer said that there is good collaboration and coordination among the internal team members at NREL and the liaison with ORNL (Tim Burress). These strong ties are a key element of the success of the program. The reviewer noted that there was less evidence of strong direct involvement from the external partners to date. The project includes both the primary effort of thermal management technologies to enable a power density target at 100 kW/l, but also a related CRADA on two-phase cooling for a high packaging density, planar inverter. John Deere is actively contributing to the related CRADA. However, the reviewer stated, the level of participation is not clear because this presentation focused on the primary effort. Elementum3D is to provide 3-dimension (3-D)-printed metal parts, presumably for the fins as well as other elements of the cooling system. However, the fins are currently produced by skiving. The reviewer hoped that these entities will become more involved with the program in the coming year.

Reviewer 7:

It was not clear to the reviewer what John Deere, Elementum3D, and ORNL have contributed.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted that the team appears to have a good plan in place.

Reviewer 2:

According to the reviewer, the PI recognizes the key barriers to the realization of the proposed technology and has developed a carefully designed approach for future research to address the barriers. This approach includes characterizing the properties and evaluating the cooling potential of not just the preferred solution of ATF, but also a range of other dielectric coolants in case ATF is too viscous or cannot achieve the cooling targets. The reviewer remarked that the approach also includes evaluating other techniques including phase-change cooling (CRADA). Other key aspects include conducting module-scale simulations to determine the optimum cooling scheme and developing cooling solutions for transient conditions. Go/no-go decision points are included.

Reviewer 3:

The reviewer opined that the decision to move towards single-phase cooling is directionally better than two-phase cooling. Previous DOE projects studied jet impingement cooling and have shown both benefits and significant challenges. Pumps and filters add cost and complexity that would typically not be acceptable to the OEMs.

Reviewer 4:

The reviewer agreed that the approach is good. The project team should verify that the 65°C inlet temperature for transmission coolant is correct and look at the possibility that the 85°C rating of the capacitor could be changed to 125°C; that could help the cooling system design.

Reviewer 5:

The reviewer called this a nice, ambitious future research proposal. It would have been nice to be clear about what the author exactly meant by “experimental demonstration.” Also, it would have been nice to hear more about “Evaluate using ATF” and “phase-change” in the last two bullet points in Slide 19. The reviewer asked if the future research includes any hardware “evaluation.”

Reviewer 6:

The reviewer remarked that the decisions do not appear to have sufficient depth in evaluation. From what can be seen, the project has embarked on evaluating a cooling method on a very incomplete power-module design concept. There needs to be a viable power-module design concept of sufficient depth as to be viable before evaluating cooling methods.

Reviewer 7:

The future research and the path forward were not quite clear to this reviewer. The main concern is how this approach is going to be implemented and tested experimentally.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer remarked that this project aims to increase the performance of thermal management systems, allowing further gains in power density.

Reviewer 2:

The reviewer said that the project objectives align well with the DOE priorities and future direction.

Reviewer 3:
The reviewer noted that thermal management is one of the critical factors to reach the DOE targets.

Reviewer 4:
The reviewer stated that reducing inverter size and weight helps to enable the EDV marketplace and reduce our dependence on foreign oil.

Reviewer 5:
According to the reviewer, most power electronics are not electrically limited but rather thermally limited and must be run at lower than maximum power to maintain the temperature in an acceptable operating range. Appropriate cooling/thermal management is, therefore, one of the most critical aspects to achieving the high 100 kW/l power density targets for 2025. The reviewer commented that this project uses innovative modifications of proven techniques to facilitate the development of electronics that can meet these aggressive targets.

Reviewer 6:
In theory, the reviewer stated that this project supports the DOE objectives. However, these cooling techniques present many challenges to meeting the objectives. Added mass, cost, and thermal system complexity are in direct opposition to meeting some of the DOE objectives.

Reviewer 7:
The reviewer indicated that the project clearly is relevant to DOE objectives as improved cooling will be critical; however, the approach as presented is weak.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer reported that the resources seem to be adequate to complete the project.

Reviewer 2:
It looked to the reviewer that the resources are currently sufficient considering the ambitious future work proposal.

Reviewer 3:
The reviewer said that resources are sufficient to accomplish the current scope of work, especially if outside participants step up their level of support.

Reviewer 4:
The reviewer noted that the resources appear to be sufficient.

Reviewer 5:
Even though the project has received the full funding, which seems to be sufficient, the reviewer commented that the authors did not presentation any cost assessment.

Reviewer 6:
The reviewer found the resources to be sufficient, but the other industry contacts are vague.

Reviewer 7:
The reviewer had stated previously that $493,000 in FY 2017 and a total budget of $968,000 seem very high for what the author presented.

Presentation Number: elt079
Presentation Title: Advanced Multiphysics Integration Technologies and Designs
Principal Investigator: Emre Gurpinar (Oak Ridge National Laboratory)

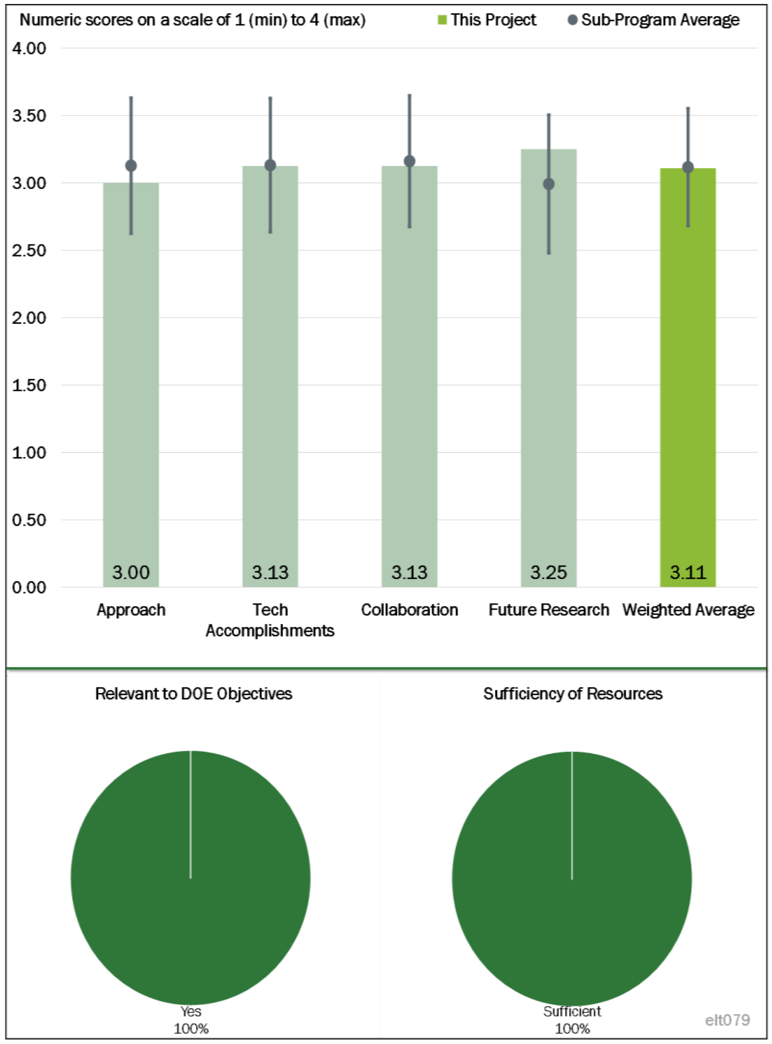

Figure 4-9 - Presentation Number: elt079 Presentation Title: Advanced Multiphysics Integration Technologies and Designs Principal Investigator: Emre Gurpinar (Oak Ridge National Laboratory)

Presenter

Emre Gurpinar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer thought that the approach is sound.

Reviewer 2:

The reviewer said that the work is divided into four areas: two materials/manufacturing and two electrical design. Research is focused on key areas that address important technical barriers, such as new substrates that provide adequate thermal management with better reliability and novel, low-profile, high-current density interconnections with reduced parasitic inductance that also reduce module size and enhance reliability. The reviewer stated that electrical research also hits key challenges, such as minimizing auxiliary and passive components, limiting parasitics, and maximizing efficiency through improved gate-driver design. Each of these projects is valuable in and of itself; however, it is not clear how these four disparate subprojects tie together into a bigger whole.

Reviewer 3:

The reviewer brought up that quilt packaging appears to be a promising method of increasing the density of control and gate-driver circuitry. Additionally, if the gate driver can be connected to the power devices with such a short connection, the devices can switch faster and with less oscillation, leading to reduced losses. The reviewer stated that amplitude modulation of the control signal is a proven method of decreasing the isolation transformer capacitance. Combining the control and power isolation onto the same transformer could be quite challenging.

Reviewer 4:

The reviewer found the technical barriers identified to be valid, though the degree to which they are addressed varies. Substrates with improved heat extraction and an insulated metal substrate (IMS) with thermal pyrolytic graphite (TPG) insert were described by this reviewer as being addressed to a high degree. Interconnects using conductive metal “nodules” on the sides of the chips was described by this reviewer as being addressed to a low degree for high-current power path. Further, inductive coupler was described by this reviewer as being addressed to a medium degree, and the isolated DC/DC converter was being addressed to a low degree.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
According to the reviewer, the team has made good progress on evaluating packaging technologies and designing the gate driver.

Reviewer 2:
The reviewer stated that significant technical accomplishments have been achieved in the first year of this program, and it is on track to deliver its milestones on time as per the timeline and milestone chart. The team selected and evaluated substrate materials. The reviewer saw that the interconnects have been tested for high-current capacity. The team evaluated several potential gate driver designs.

Reviewer 3:
The reviewer commented that progress is acceptable in accordance with the project plan.

Reviewer 4:
The reviewer recommended that the project team focus on the highest value concepts with regards to the IMS with TPG insert and maybe the chip-to-chip connections. Gate-drive signal isolation and power supply are adequately addressed in other institutions and industry.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that strong collaborations have been evinced through the substantive involvement of the external partners. Momentive working with Berquist/Henkel has supplied the thermal pyrolytic graphite insulated metal substrate along with thermal conductivity and reliability data. Indiana Integrated Circuits performed the current carrying capability study of the quilt packaging interconnections. NREL provided the thermal modeling. The reviewer remarked that this level of interactions shows excellent team coordination.

Reviewer 2:
The reviewer stated that collaboration appears good.

Reviewer 3:
According to the reviewer, the team is working with several organizations for packaging technologies and with NREL for thermal management research.

Reviewer 4:
The reviewer noted that collaboration and coordination across the team is good and the team is well-formed.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer pronounced the proposed future work is sound and in alignment with the objectives.

Reviewer 2:
According to the reviewer, the proposed future work is in keeping with moving the program forward and addressing key challenges and risks, such as proper selection of substrate and voltage standoff studies for the interconnections. Future research provides go/no-go decision points at appropriate junctures. The reviewer stated that it would be good for the goal of this future research to produce an actual prototype that included all of these four elements in a single converter.

Reviewer 3:
The reviewer indicated that the team has a good plan in place.

Reviewer 4:
The reviewer recommended the team focus on highest value concepts, with regards to the IMS with TPG insert and that may be the chip-to-chip connections. Gate-drive signal isolation and power supply are adequately addressed in other institutions and industry.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer opined that this project can lead to increased power density and better control over power devices.

Reviewer 2:
The reviewer thought that the project supports the DOE objectives as the project attempts to develop power-module technologies to improve the SiC power module and ancillary components.

Reviewer 3:
Yes, the reviewer said, this project supports the overall DOE objectives of reduced cost, size, weight, and increased power density. Each of the elements of this program is moving towards creating converters with one or more of the following improved characteristics: higher power density, lower parasitics, higher efficiency, faster switching, and higher reliability,

Reviewer 4:
The reviewer's response was that there is relevance to varying degrees: Substrates with improved heat extraction, and IMS with TPG insert to a high degree; interconnects using conductive metal "nodules" on the sides of the chips to a low degree for a high-current power path; inductive coupler to a medium degree; and isolated DC-DC converter to a low degree.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
It seemed to the reviewer that the resources are adequate to complete this project.

Reviewer 2:
According to the reviewer, resources are sufficient, especially given the level of external cooperation.

Reviewer 3:
The reviewer stated that the project appears to have sufficient resources.

Reviewer 4:
The reviewer recommended a close look at focusing resources on those technologies that have shown the highest potential in year 1.

Presentation Number: elt080
Presentation Title: Performance and Reliability of Bonded Interfaces for High-Temperature Packaging
Principal Investigator: Paul Paret (National Renewable Energy Laboratory)

Presenter

Paul Paret, National Renewable Energy Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

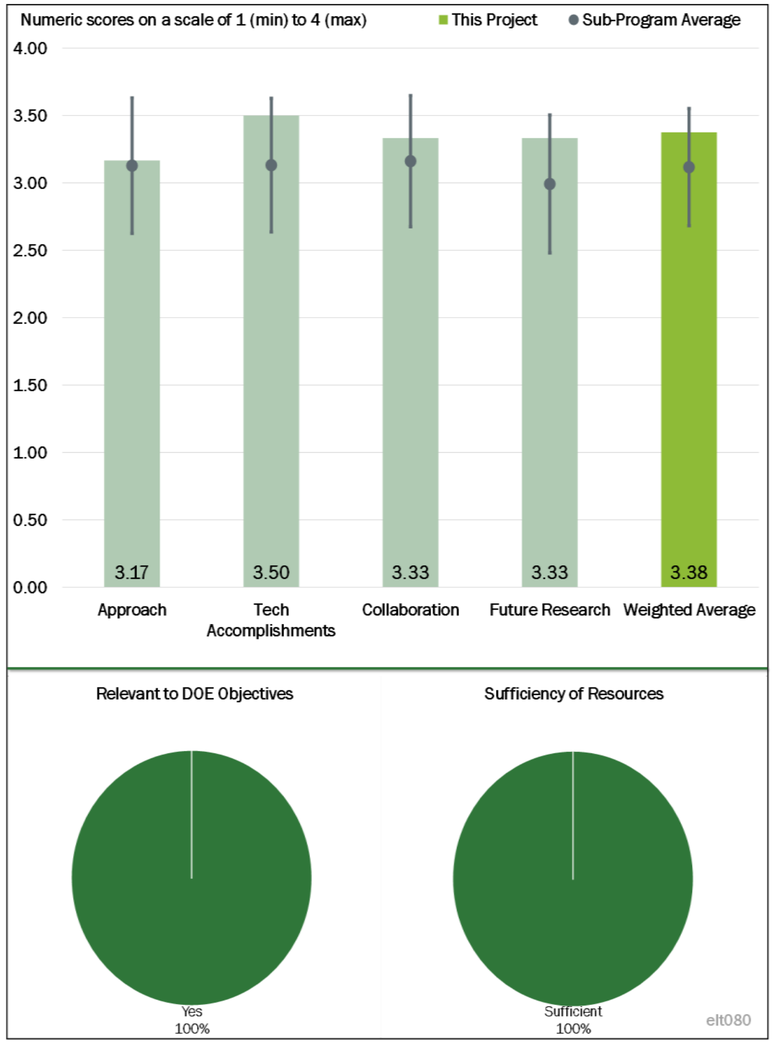

Figure 4-10 - Presentation Number: elt080 Presentation Title: Performance and Reliability of Bonded Interfaces for High-Temperature Packaging Principal Investigator: Paul Paret (National Renewable Energy Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the approach is excellent; however, the round double-lap test samples are not representative of what is used in industry. Dies are square or rectangular, not round so the die attach should be square or rectangular. Perhaps adding square or rectangular double-lap samples with the round samples would be more representative. The reviewer asked that the graphs of shear-test results have a line drawn showing what is considered acceptable.

Reviewer 2:

The reviewer commented that putting together models to be developed and testing hardware are essential and good. According to the reviewer, validity in applying the J-integral as one of the modeling approaches to this particular purpose needs explanation. The reviewer stated that it would have been nice to explain how the results for the circular-shaped test samples can be correlated with the square-/rectangular-shaped test samples because the square-/rectangular-shape is practically dominated in the actual application field.

Reviewer 3:

The reviewer wanted to know what the technical approach is to achieve the pressure-less sintering.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found the test and modeling results to be good. The thought process to determine the sintering process profile (temperature, pressure, and time) was not quite clear, and the reviewer asked for an explanation.

Reviewer 2:
The reviewer pronounced the approach of build and test, predict reliability, and create a model to be perfect. While this is still a work in progress, it is well done.

Reviewer 3:
This reviewer stated not applicable.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team appears to be working well together, according to the reviewer.

Reviewer 2:
The reviewer noted that the collaboration with Virginia Tech and ORNL is good. The reviewer asked for more clarity about "Private industries in power electronics" on Slide 16. The reviewer wanted to know who those private industries are and what they are contributing to.

Reviewer 3:
No response entered.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
According to the reviewer, the project team is following the approach of build and test, determine reliability, and create model; the team is focused.

Reviewer 2:
The reviewer asked for a description of a plan to verify the developed lifetime prediction model. The reviewer said that it is good that the future proposal includes other high-temperature bonded interface alloys, such as copper-aluminum and copper-tin.

Reviewer 3:
The reviewer wanted to know how to enable the pressureless sintering to achieve the performance similar to regular high-pressure sintering. The reviewer wanted to know what the criteria and projected performance goals are for the success of the project.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that new reliability questions need answering for a full utilization of new wide bandgap power devices with cost-effective packaging. Hence, the reviewer said that this project is quite relevant.

Reviewer 2:
The reviewer remarked that improving reliability of the power electronics is very important (refer to the Prius 2014 inverter issues as a reference), thus allowing EDVs to last longer while reducing costs and lowering our dependence on foreign oil.

Reviewer 3:
This reviewer stated not applicable.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
It looked to the reviewer that the resources are currently sufficient considering the proposed future research.

Reviewer 2:
The reviewer commented that the resources are sufficient and the team is qualified.

Reviewer 3:
This reviewer stated not applicable.

Presentation Number: elt089
Presentation Title: Assessing the North American Supply Chain for Traction Drive Inverters, Motors, and Batteries for Class 3-8 Hybrid Electric and Plug-In Electric Commercial Vehicles
Principal Investigator: Chris Whaling (Synthesis Partners)

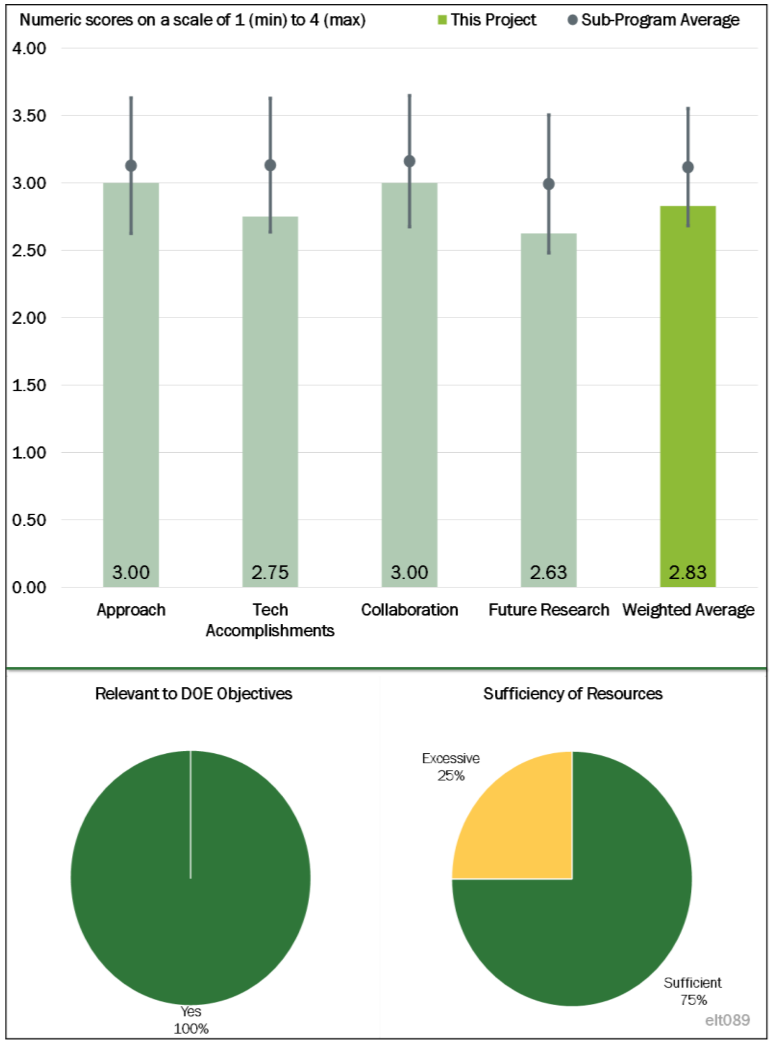

Figure 4-11 - Presentation Number: elt089 Presentation Title: Assessing the North American Supply Chain for Traction Drive Inverters, Motors, and Batteries for Class 3-8 Hybrid Electric and Plug-In Electric Commercial Vehicles Principal Investigator: Chris Whaling (Synthesis Partners)

Presenter

Chris Whaling, Synthesis Partners

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, there is a satisfactory approach to collecting data and establishing modeling and analysis. The reviewer was interested in seeing the gaps and potential concerns with the supply chain.

Reviewer 2:

The reviewer thought that the approach could have benefited from targeting the ability to offer higher fidelity in the data. For example, the class of commercial vehicles is very wide, with varying power and energy requirements (energy storage, motor sizing, etc.) and duty cycles (long haul, urban duty cycle); in order to truly assess supplier capability and readiness, one needs to understand what range of products the project team can supply or have supplied (motors/batteries sized for 15,000 pounds gross vehicle weight [GVW] for a hybrid vehicle or 30,000 pounds GVW for an EV). When the reviewer asked a follow-up question about whether or not these distinctions would be made to truly understand supplier status, the reviewer was unsure whether this would be available or if the presenter comprehended the importance of these data.

Reviewer 3:

It was not clear to the reviewer why an analysis of the quantity of electric trucks presently on the road is necessary. The reviewer wondered if that information could be gathered from the appropriate OEM’s and asked why the analysis could not be based on a future population of vehicles. One of the goals is to establish and understand gaps in the supply chain. Because OEM, Tier 1, and Tier 2 companies are involved with Class 3 through Class 8 manufacturers who deal with various and different supply chain issues, this project objective seems overly complex to identify with the current work plan.

Reviewer 4:

The reviewer commented that the focus of this project is to identify the gaps, constraints, and bottlenecks in the North American supply chain for traction-drive electrification components (inverters, motors, and batteries) for hybrid electric and plug-in electric commercial vehicles (Class 3-8). The reviewer noted that a number of specific barriers have been identified, including accurate information about Class 3-8 electric commercial vehicles and their supply chains and actionable intelligence on research and development (R&D) gaps that affect autonomous vehicles and Class 3-8 power electronics, batteries, and motors in North America. Other barriers identified include time to process and analyze large amounts of heterogeneous data, accessibility of primary sources both in-person and electronically, navigation to highest value data via source confidentiality agreements, and opportunities to drill-down with subject matter experts (SMEs) on specific Class 3-8 electric commercial vehicle (ECV) R&D gaps.

The reviewer found the Synthesis Partners approach to be logical, well designed, and feasible by addressing many (but not all) of these barriers. The approaches comprise identifying appropriate customer (VTO) questions to be answered, data collection from primary (direct person-to-person discussions) and secondary (research) sources, modeling of quantitative and qualitative data, analysis with gap identification, and a final report with findings and next steps. The reviewer remarked that the approach seems to have cast a relatively broad net including personal communications (direct and email) and electronic sources.

Two questions existed though in the reviewer's mind: It is not clear to the reviewer how the approach specifically addresses time to process and analyze large amounts of heterogeneous data and how to navigate to the highest value data via source confidentiality agreements. Additionally, it is not really clear to the reviewer what modeling of quantitative and qualitative data entails and how this will be of overall benefit.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that solid technical progress has been made on this project and it seems basically on schedule. This includes completing the report "R&D Gap and Trend Analysis for Autonomous and Connected Vehicles; On Connectivity, Sensors and Sensor Systems (November 2017); 340+ individuals within 220 organizations contacted to elicit information with regards to the North American (NA) supply chain for medium-duty (MD) and heavy-duty (HD) vehicles and associated power electronics, motors, and batteries; production of initial, detailed Class 3-8 component supplier datasets; and sharing of datasets with NREL and ORNL for review and comment. More than 10 initial gaps have been identified in the Class 3-8 North American supply chain.

A question that exists in the reviewer's mind is whether analyses will attempt to look into the future based on what is found in the present state. In other words, the reviewer wanted to know if this project will make any attempt to prognosticate the future for the NA supply chain for inverters, motors, and batteries for commercial HEVs and PHEVs.

Reviewer 2:

It seemed to the reviewer there has been an effort to collect data from the industry, and so the groundwork has been laid to achieve the project goals. For this presentation in June, the reviewer stated that it would have been better to have seen the data analysis further along, given that there are 3 months until the end of the project. Many of the slides were marked as of "April" where it would have been better to see current data. For example, the statement on Slide 14, "Allison H 3000 product on scheduled to begin in Q4 2013," gave the reviewer concern that the data will be the surface level. In the example given, verification of this can be obtained through SEC filings with the company as well as a lot of other data. The reviewer expressed concern that the data may not go deep enough to truly achieve project objectives, or the PI does not completely understand the significance.

Reviewer 3:
The PI did not make the presentation, according to the reviewer; however, it appears that specific supply chains are not identified, although a large collection of suppliers have been contacted. The reviewer did not see how the project collected those data in an objective manner. Furthermore, the reviewer wanted to know the definition of a gap and whether it is the lack of project, a cost that is too high, or something else.

Reviewer 4:
The reviewer pointed out that the presenter was not able to answer specific technical questions when asked.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The overall collaboration and coordination for this project seems strong according to the reviewer. The project has indicated collaborations with a number of entities including: OEMs and Tier 1-4 suppliers, R&D organizations, universities, national laboratories (NREL and ORNL), the U.S. DRIVE Electrical and Electronics Technical Team (EETT), and other VTO stakeholders. The reviewer opined that the distribution of primary sources exhibits a strong mix including senior and mid-level executives, universities, research laboratories, non-profits, and government.

Reviewer 2:
The reviewer believed there was good coordination to be able to go out and actively seek data from OEMs, which can be hard to gather. It is hard to assess at this point whether the best-quality contacts were attained to get all the data needed.

Reviewer 3:
The reviewer believed that a collaboration with a university business school would provide a benefit to the project.

Reviewer 4:
The reviewer stated that the company was able to obtain current supply-base information, but did not provide a forecast or timeline of future supply capabilities.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer responded that the next step is planned to be completed in September and is logical and on time.

Reviewer 2:
The reviewer found the approach to analyze the data to be good. The reviewer had expected an outlook into the future for suppliers' capabilities and a technology roadmap.

Reviewer 3:
This is a 1-year project scheduled to end in September 2018 and has not really identified proposed future work. However, the reviewer asked about any value to comparing the final results of this study to any similar prior studies by other organizations. This may help establish some historical trend lines and build the knowledge base to lay a foundation for future prognostication.

Reviewer 4:
The reviewer stated that it was somewhat unclear about what remains to be accomplished and what, if anything, would be proposed for future work.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer mentioned that the U.S. DRIVE Partnership Goal 1 is to "Enable reliable hybrid electric, plug-in hybrid and range-extended electric and battery electric vehicles with performance, safety, and cost comparable to or better than advanced conventional technologies." According to the reviewer, a robust and secure North American supply chain for inverters, motors, and batteries is essential to achieve this goal.

Reviewer 2:
The reviewer said yes. The reviewer believed that understanding the supplier capability is important to understanding their capability to develop and apply new technology. The reviewer also believed the project could have benefited from further scoping to make sure the assessment provided data on the supplier capability in terms of HEV or EV (power and energy capability for the products they have).

Reviewer 3:
The reviewer noted that this project absolutely supports DOE relevance by providing a study of the supply chain of electric HD vehicle systems and components. It might go further by also reviewing costs of the components and systems at a future state.

Reviewer 4:
The reviewer commented that there was important information for planning and capabilities.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed that the resources identified for this project ($460,000) should be sufficient for this project and the stated objectives and milestones identified therein.

Reviewer 2:
The reviewer stated that resources and the timeline to finalize seem to be on track.

Reviewer 3:
The reviewer said that resources are sufficient although the reviewer would recommend gaining third-party business analysis support from a university.

Reviewer 4:
The reviewer asserted that $459,918 of total project funding is excessive for the data requested and seen thus far in this project. As outlined in the presentation, the work considered is: 50+ conversations with SMEs plus 500 phone calls plus 1,000 electronic sources reviewed, attendance at APEC 2018, and constructing the database. The project was funded 100% by DOE. If the PI conducting the research has sufficient contacts within the industry already so that the project team can more readily start data population, then the reviewer opined that it would be reasonable to assume that awarding based on that intellectual property would pay for no more than 1 man-year worth of work for these tasks. The reviewer stated that $250,000-$300,000 should be sufficient to pay for this as well as any travel required to meet in person or fill the rest of the gaps in research. The reviewer commented that many potential PIs who have worked in the field (for example, at the OEMs or suppliers mentioned in the presentation) would be able to fill such a role. If the PI does not have sufficient contacts to readily do this research, then it seemed to the reviewer that the cost should be shared because the PI is gaining prestige from making further contacts in the industry and is able to use those contacts for future work. Even if this is the case, then the $459,918 should be shared 50% between the PI and the DOE.

Presentation Number: elt090
Presentation Title: Dual-Phase, Soft Magnetic Laminates for Low-Cost, Non-Reduced Rare-Earth Containing Electrical Machines
Principal Investigator: Francis Johnson (GE Global Research)

Presenter

PR Subramanian, GE Global Research

Reviewer Sample Size

A total of two reviewers evaluated this project.

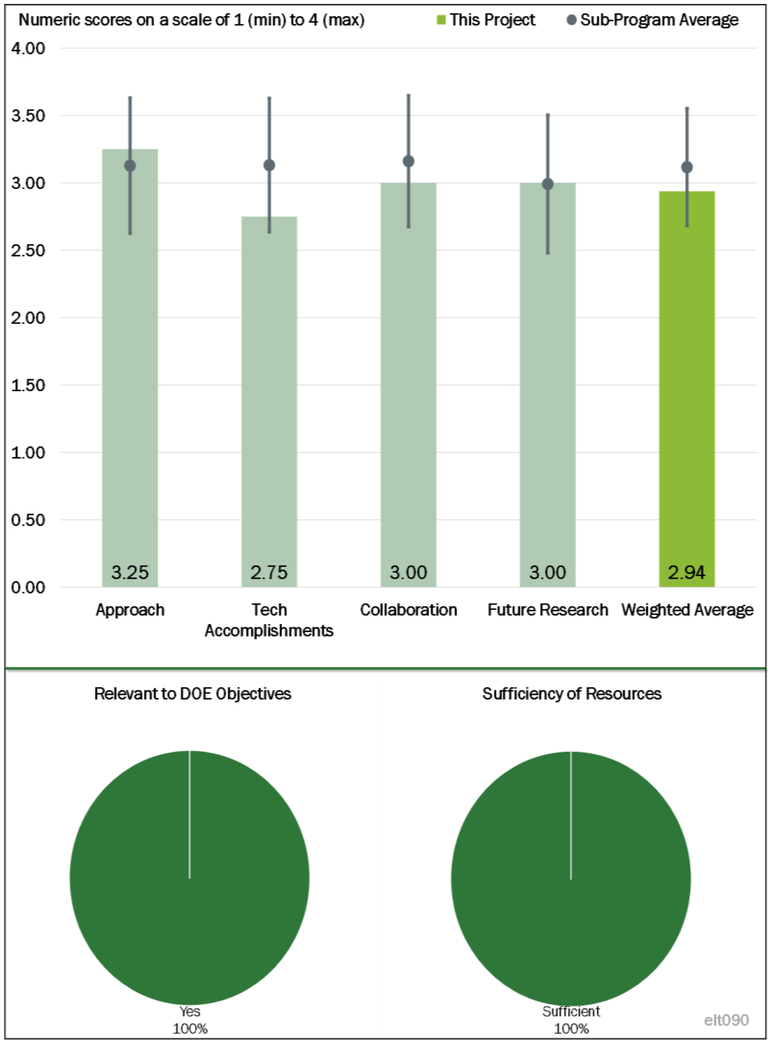

Figure 4-12 - Presentation Number: elt090 Presentation Title: Dual-Phase, Soft Magnetic Laminates for Low-Cost, Non-Reduced Rare-Earth Containing Electrical Machines Principal Investigator: Francis Johnson (GE Global Research)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the approach taken by the team is good. Building a subscale prototype and evaluating its performance will be an important step before building the 55 kW prototype. However, the reviewer could not find the subscale motor specification. The reviewer was curious to know how specification was scaled down. If the team uses specific scaling laws for the two machines, then the reviewer can get more insights into the designs.

Reviewer 2:

The reviewer posited that this dual-phase alloy for synchronous reluctance motor looks unique and is an interesting approach, but it was not clear to the reviewer as to the specific motivations to go to a synchronous reluctance motor. The reviewer also suggested that a reasonable route to consider is a non-heavy RE interior permanent magnet (IPM) motor assisted by higher reluctance with this dual-phase alloy. Also, specific challenges and potential roadblock description are expected as key outputs.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the project period is October 2016 to September 2019. With a year left to go, the reviewer thought that one of the major risks that needs to be alleviated is a clear understanding of the tradeoff between mechanical and magnetic properties. According to this reviewer, the tradeoff is at the heart of the success/failure of this project. While there were significant accomplishments, the reviewer wished that this risk had been addressed much earlier in the program period.

Reviewer 2:
The reviewer observed reasonable progress for the motor prototyping. The reviewer asked if there has been any study carried out for long-term mechanical and magnetic characteristics change for this particular dual-phase alloy.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
According to the reviewer, collaboration with a national laboratory and other industry partners is good.

Reviewer 2:
The reviewer said that collaboration exists and it is apparent that the individual team members are working based on their individual commitments.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer thought that one of the key barriers that needs to be addressed is the tradeoff between the mechanical and the magnetic properties. While building prototypes are perfect to prove the technology, without this key understanding, the project can remain as an industrial research/one-prototype experiment rather than a technology that can be transferred to the automotive world.

Reviewer 2:
The reviewer stated that it is fair to bring up DOE 2020 target. But, the reviewer said that it may also be a good idea to look at the updated U.S. DRIVE EETT roadmap, because the motor power rating is now higher than the targets stated in the Slides 2 and 4. The reviewer accordingly recommends looking into scalability of this work to meet the new electric motor target.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer opined that cost-effective and high power-density electric motor development is one of the keys for EV penetration into the market. New, soft magnetic material technology is a key enabler to realize it.

Reviewer 2:
According to the reviewer, the project, if successful, will be highly relevant for DOE VTO mainly due to the impact it can have in terms of meeting the DOE target comfortably. However, the reviewer's only concern was that the project has not mitigated one of the highest risk elements.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer thought that the team has enough resources to meet the project goal.

Reviewer 2:
It looked to the reviewer that the resources are currently sufficient considering the proposed future research.

Presentation Number: elt091
Presentation Title: Cost-Effective 6.5% Silicon Steel Laminate for Electric Machines
Principal Investigator: Jun Cui (Iowa State University)

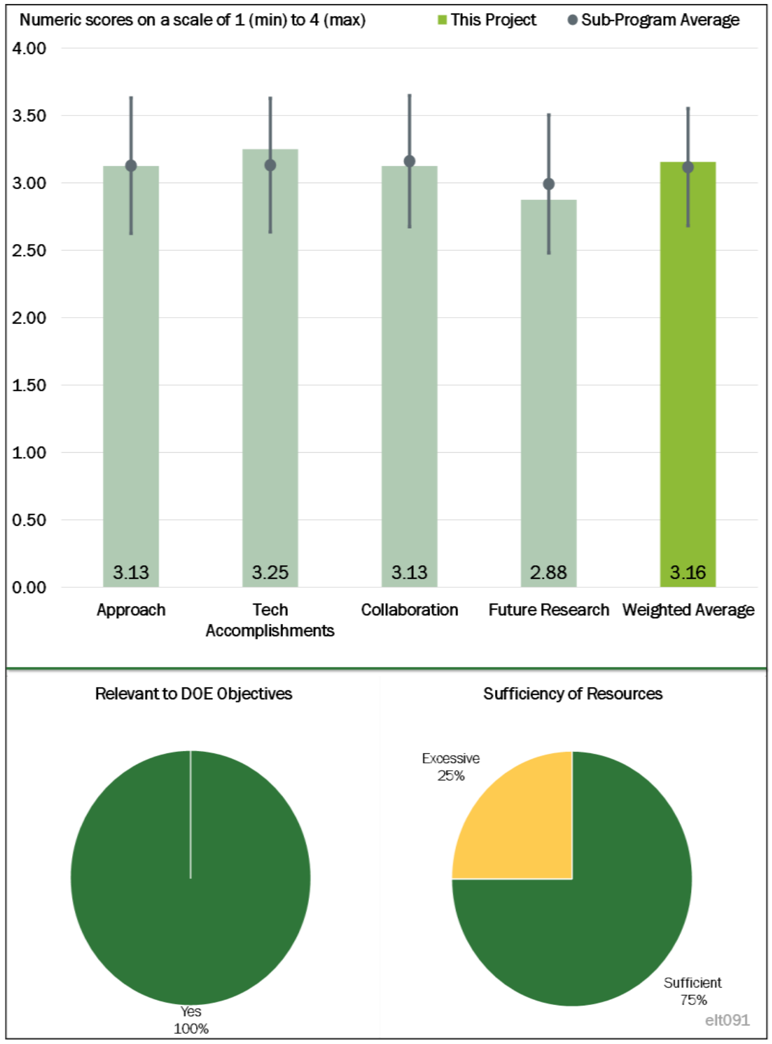

Figure 4-13 - Presentation Number: elt091 Presentation Title: Cost-Effective 6.5% Silicon Steel Laminate for Electric Machines Principal Investigator: Jun Cui (Iowa State University)

Presenter

Jun Cui, Iowa State University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer praised the work done by the team on materials development as outstanding. The sample the team presented in the review meeting gave the reviewer more confidence in hoping that one day this material will be a reality and will be used to make more efficient machines.

Reviewer 2:

The reviewer had several concerns about the project. It was not clear to the reviewer that MnBi magnets can provide a realistic path to replace RE NdFeB magnets while achieving the required performance metrics. Even though the PI mentioned that one of the key enablers is to go to high frequency/speed, the 400 Hertz (Hz) targeted frequency is fairly low compared to current traction motors.

The 6.5% silicon steel can lead to higher efficiency, but it was not clear to the reviewer how this can enable non-RE designs. Also, this material can be used with RE designs as well. In general, the reviewer stated that the project seems to be pursuing two or three technical areas that do not seem to be tied together and it was not clear how they can end up providing a comprehensive solution for the RE challenge.

Reviewer 3:

The reviewer said that studying MnBi as an alternative PM material candidate is a worthy activity, considering its unique characteristics of coercivity increasing with temperature increase. Cost-effective production process of 6.5% Fe-Si with maintaining its mechanical strength is also worth looking into in order to achieve the electric motor cost target. Also, this reviewer expected a description of specific challenges and potential roadblock as expected as key outputs.

Reviewer 4:

The approach was unique in that the project team planned to develop practical 6.5% SiFe as an enabler to use MnBi magnet materials to make up for the reduced magnetic properties of MnBi with respect to RE materials. The increase in relative permeability of 6.5% SiFe with respect to 3.2% SiFe alone does not seem enough to make up the gap in remanence for the MnBi to RE materials.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the team has accomplished the targets very well so far. The fabricated rings look impressive.

Reviewer 2:

The reviewer reported that the team is making great progress in terms of producing MnBi with better magnetic properties and 6.5% SiFe with better mechanical properties. The author showed samples during the presentation and progress appears to be very good with respect to the goals.

Reviewer 3:

The reviewer appreciated the incremental increase of saturation magnetization (M_S) and theoretical energy product (BH_{max}). Wheel speed versus mechanical property relation is informative. The reviewer asked what application assumption led to the choice of a 10-kW peak and 6-kW continuous-rated power motor. The reviewer opined that this is a way low power rating for electrified powertrain applications. The reviewer expected a motor scalability study.

Reviewer 4:

The reviewer observed that progress made on addressing the brittleness of the 6.5% silicon steel is good but scalability needs to be proven. It was not clear to the reviewer that the chosen motor specifications or topology (surface PM) is very relevant to the ultimate DOE specifications.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that there was good collaboration between Iowa State University and United Technologies Research Center (UTRC).

Reviewer 2:

According to the reviewer, there is quite a broad and good range of collaboration of national laboratories, universities, and industries.

Reviewer 3:

The reviewer complimented the program has having many reputable partners in their respective areas and the progress of the program is going very well, especially considering the number of partners to coordinate.

Reviewer 4:

To this reviewer, there seemed to be a disconnect between the team at Iowa State and UTRC, who are almost independently working on this project. What is not clear to the reviewer is how UTRC is going to use the materials developed by the Iowa State. Owing to a large number of members in the team, it was difficult for the reviewer to assess how the rest of the team members are contributing to the project. It was not clear in the presentation.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the program has planned further improvement in MnBi and 6.5% SiFe, then building a motor with these materials for demonstration. Demonstration of hardware is always the best way to prove the merits of the development efforts.

Reviewer 2:

According to the reviewer, the future proposed research is interesting from the materials development perspective. However, how these materials will be used to improve motor-power density to 5.7 kW/l is not so obvious.

Reviewer 3:

Similar to some previous comments, the reviewer affirmed that it is important that the research team re-visit the approach and confirm that, even if successful, the developed materials will really enable a feasible rare-earth free design. Also, the reviewer stated that it is important to confirm that the motor prototype is really designed based on relevant specifications.

Reviewer 4:

The proposed direction about MnBi and 6.5% Fe-Si is good, according to the reviewer, who asked why a 400Hz PM motor is being proposed. It looked to the reviewer as if an aerospace application is under consideration. Also, the reviewer questioned if it is just a 10-kW power rating. The reviewer encouraged the project team to refer to the DOE U.S. DRIVE EETT roadmap about the motor development expectations and work on a scalability study.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer remarked that the project is highly relevant from the DOE perspective. If successful, the 6.5% Si steel can drastically impact the performance of electric machines.

Reviewer 2:

The reviewer stated that the project is an ambitious project that tries to address significant issues with two materials. Its ultimate goal is to develop RE free motor designs, which is consistent with DOE's vision.

Reviewer 3:

Cost-effective and high power-density electric motor development is one of the keys for EV penetration into the market, according to the reviewer. Both permanent magnet material and soft magnetic material are key enablers to realize it.

Reviewer 4:

It appeared to the reviewer that the 2020 targets could be within reach, which are the goals stated for the program. There will likely be a large gap between 2025 targets and any tested result; however, these were not original goals. The 6.5% materials also have other advantages in terms of efficiency gains due to the lower resistivity of the materials with respect to 3.2% material.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

It seemed to the reviewer that the team has sufficient resources to complete the project in a timely manner. They have done well so far.

Reviewer 2:

The reviewer stated that resources seem sufficient based on the proposed scope.

Reviewer 3:

It looked to the reviewer that the resources are currently sufficient considering the proposed future research.

Reviewer 4:

The reviewer noted that there are many contributors to this program; may be appropriate due to the scope of the program touching many different areas and disciplines.

Presentation Number: elt092
Presentation Title: Wound Field and Hybrid Synchronous Machines for Electric Vehicle Traction with Brushless Capacitive Rotor Field Excitation
Principal Investigator: Ian Brown (Illinois Institute of Technology)

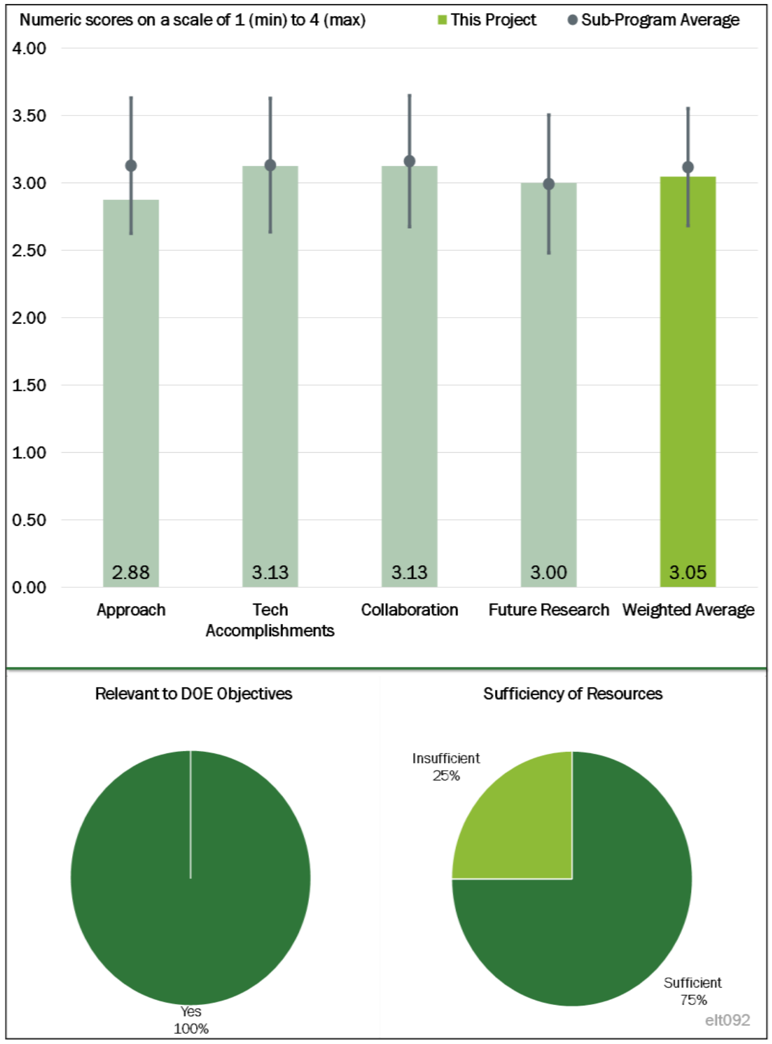

Figure 4-14 - Presentation Number: elt092 Presentation Title: Wound Field and Hybrid Synchronous Machines for Electric Vehicle Traction with Brushless Capacitive Rotor Field Excitation Principal Investigator: Ian Brown (Illinois Institute of Technology)

Presenter
Ian Brown, Illinois Institute of Technology

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer observed that the approach seems original and unique in both the WFSM with capacitive power coupler and the hybrid excitation synchronous machine (HESM). Both seem to have merit for decreasing cost and the power factor leading to inverter cost savings. The only concern the reviewer had is the split in focus on the two different tracks as well as the development of multiple technologies and motor prototypes. However, all seem appropriate in meeting the stated DOE 2020 targets. The reviewer would have liked to have seen an analysis of complete system cost reduction, including inverter cost reduction due to optimizing power factor (PF).

Reviewer 2:
According to this reviewer, the fundamental concept is interesting. However, there are many moving pieces in this project. It became very difficult for the reviewer to comprehend what affects what as everything is being changed and is a part of the design process. While this approach opens up flexibility, it also introduces a bit of a chaos and randomness. There are way too many prototypes being built and tested, diluting the project’s goal. Also, a clear takeaway from each prototype built is also missing. The reviewer was curious to know how this will all contribute to/merge together to meet the project objectives.

Reviewer 3:
The reviewer stressed the authors have to make clear that the project is pursuing two parallel paths, including the wound-field synchronous machine as well as the hybrid wound-field synchronous machine; ultimately, one approach will be down-selected. The reviewer suggested providing a detailed comparison of the proposed

topologies versus a baseline RE IPM design. There are several design pieces proposed according to the reviewer, and it is not easy to quantify the relative impact of each of them. The authors should provide some sort of a quantitative summary/waterfall chart of the impact of the various design factors (capacitive power transfer, pre-pressed windings, control, etc.). The reviewer had a lot of concern about the capacitive power transfer and the very high frequencies required in the megahertz (MHz) range. This can pose serious challenges in a real application, especially in terms of reliability. The proposed hybrid topology is fairly complicated. Similar approaches were previously proposed in literature and did not materialize commercially, mainly because of the level of complication.

Reviewer 4:
The reviewer suggested that hybrid excitation is worth investigating as an alternative candidate of interior permanent magnet synchronous motor (IPMSM) with heavy RE. The approach covers from material utilization (low scrap designs) to control scheme, which is very good. Also, the reviewer stated that the possibility of unity power-factor operation is attractive for drive-inverter. The reviewer said that it would be nice to have a description regarding why the capacitive power transfer has been chosen here, in particular, compared to the magnetic power transfer. It is fair to aim to meet 2020 target (55 kW, etc.), but because the updated target for 2025 has now been released with higher power ratings, the reviewer suggested that it would be a good idea to include a scalability study on this particular approach.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer found very good progress in various directions in baseline machine prototyping, winding options, electromagnetic and thermal optimization, and a control scheme study.

Reviewer 2:
Technical progress also appears to be on track, according to the reviewer, and is impressive considering the technical challenges. The completion of a prototype motor and separate capacitive power coupler (CPC) has been attained and demonstrated to some degree.

Reviewer 3:
The reviewer pointed out that the project definitely has created many prototypes with many design variations. However, it is not clear how each of these prototypes measures against the performance indicators. The team is attacking machines, controls, brushless power couplers, and capacitive power-transfer inverters. The reviewer mentioned that a clear presentation of how all of these merge together to create the complete drive would be essential to understanding the merit of the project.

Reviewer 4:
The reviewer said that the team has made good progress but there are still several challenges and risks to address.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
It seemed to the reviewer that there is good collaboration between the team members.

Reviewer 2:
There is good collaboration between Illinois Institute of Technology and University of Wisconsin at Madison according to the reviewer.

Reviewer 3:
The reviewer found collaboration to be good among universities and an industry partner.

Reviewer 4:
The reviewer stated that collaboration seemed to be going well considering the progress.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
There is a good plan to address several of the remaining challenges according to the reviewer.

Reviewer 2:
The reviewer said that the scope planned for budget period (BP) 2 and BP 3 is comprehensive and aggressive. A lot of value in learning will be produced if the goals can be accomplished. The track record to date indicates that this group can accomplish it.

Reviewer 3:
The reviewer found the step-by-step incremental prototype machine building and testing plan to be good. Electrified powertrain community has a question mark regarding the long-term reliability of the GaN device. Hence, if GaN devices are avoided, the reviewer asked about the limitations and/or trade-offs for an alternative. For example, the reviewer wanted to know how low a frequency can one go if the alternative does not allow going with 2 MHz for capacitive power transfer and a certain assumption of capacitor size.

Reviewer 4:
The reviewer remarked that the proposed research is interesting but there are too many moving pieces without a clear vision of the end objective.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that the project is highly relevant to the overall DOE objective. If this research is successful, a new technology can be taken to market that fits the DOE target for the electric vehicles.

Reviewer 2:
The reviewer noted that the project is pursuing RE reduced/free designs, which are in line with the DOE's vision.

Reviewer 3:
The reviewer stated that cost-effective and high power-density electric motor development is one of the keys for EV penetration into the market. The approach taken in this project is worth in-depth investigation as a candidate to take over the role of interior permanent magnet synchronous motor with HREs.

Reviewer 4:
The relevance is a yes, but the reviewer had some major qualifiers. The added expense of the CPC and the associated inverter and peripherals seems significant, and it is difficult to see that it will be offset the main inverter cost savings due to PF improvements. The reviewer stated that machine construction and HESMs do not seem to have major drivers in terms of cost savings. Again, a cost analysis at the system level would be helpful in evaluating these potentially offsetting savings factors.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

It seemed to the reviewer that the team has sufficient resources to achieve the stated milestones within the period of the project.

Reviewer 2:

Resources are sufficient for the proposed scope.

Reviewer 3:

It looks that the resources are currently sufficient considering the proposed future research.

Reviewer 4:

Though the size of the team among the different collaborators is unknown, it seemed difficult to the reviewer to produce all that is planned. That being said, the progress to date has been significant; therefore, there is no reason to believe the scope cannot be accomplished.

Presentation Number: elt093
Presentation Title: High-Speed Hybrid Reluctance Motor with Anisotropic Materials
Principal Investigator: Edwin Chang (General Motors)

Presenter

Edwin Chang, General Motors

Reviewer Sample Size

A total of four reviewers evaluated this project.

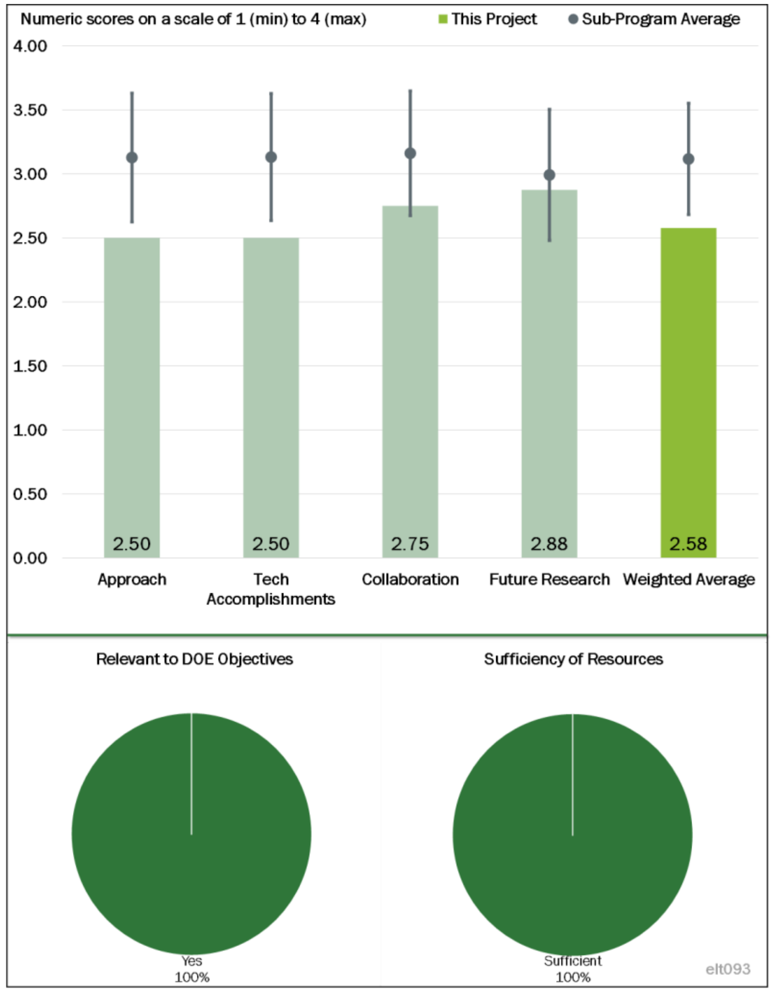

Figure 4-15 - Presentation Number: elt093 Presentation Title: High-Speed Hybrid Reluctance Motor with Anisotropic Materials Principal Investigator: Edwin Chang (General Motors)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that bringing up multiple options with three variants is good for various electrical machine concepts.

Reviewer 2:

The novelty of the project was not clear to the reviewer. All the machine topologies/variants are well known and have been extensively investigated in the literature.

Reviewer 3:

The approach seemed reasonable to the reviewer relative to the stated goals being 2020 targets and results show power density targets are exceeded. However, most of these architectures appear to have been done before, with the exception of the improved aluminum-copper interface for induction or any novelty to the architectures that were not disclosed.

Reviewer 4:

The reviewer stated that the project started in October 2016 and is supposed to end in September 2019. With only a year left (almost), the team is claiming to have completed 40%, which is way on the lower side. More interestingly, from the results in Slides 9-11, it seems all the variants meet the DOE targets, which seems a bit unrealistic. Some of the design variants achieve power density way more than the target specification. The reviewer suggested that more detailed analysis and supporting arguments would be better to understand if the results make sense, and if they do, then there needs to be an explanation for why all motor types can attain the spec.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer indicated that materials selection has been accomplished and evaluation of the aluminum-copper interface has been accomplished though it appears fatigue testing is slated for BP 3. It was unclear to the reviewer if the non-HRE material is off the shelf or developed. Most work done so far appears to be analysis, though it also appeared to the reviewer that a thorough analysis and planning phase has been completed.

Reviewer 2:
The reviewer recommended that the key results that were presented need to be evaluated and justified. It seemed to the reviewer that all the probable variants will meet the DOE specification, which is bit surprising. Nonetheless, a more detailed justification would be better to argue why all the design variants match the spec.

Reviewer 3:
It was not clear to the reviewer how the significant increase in specific power and power density is accomplished using fairly traditional machine topologies. There is no information regarding efficiency. There is no information about current density and thermal management of the machines. The condition of 120% of rated current to check demagnetization is typically not a good representation of fault conditions, according to the reviewer. A clear, comprehensive comparison of the proposed designs versus a baseline IPM with RE magnets should be provided.

Reviewer 4:
The reviewer was not quite clear about what non-heavy RE permanent magnet materials are referred to with “grade 1”, “grade 2” and “grade 3” on Slide 7. It was unclear what is meant by “Optimized Cu-Al bar” and “Base Cu-Al” bar. Without more technical details regarding those unclear factors, it was very difficult for the reviewer to comment.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer asserted that there was good collaboration between GM and ORNL.

Reviewer 2:
The reviewer found the collaboration between industry and a national laboratory to be good.

Reviewer 3:
ORNL is the only identified collaborator and it was unclear to the reviewer what type of materials testing the laboratory is doing.

Reviewer 4:
The contributions of the individual team members were not very clear to the reviewer. It seemed to the reviewer that there is collaboration, but the presentation seemed to lack detailed support from other team members in highlighting the key results of the tasks so far.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that building and testing prototypes is critical to prove predicted performance as well as to flush out any manufacturing issues.

Reviewer 2:
The reviewer remarked that future work includes building and testing the motor variants. This is appropriate given that much of the development is at the motor level. Endurance testing is also appropriate as part of the testing due to the nature of the work. The reviewer was not sure why slot fill is also included as it does not seem related to the other development, but nonetheless can improve torque and power density if the design is reiterated.

Reviewer 3:
The reviewer commented that a detailed analysis is required to justify why three design variants match the specification. The remaining challenges were not very clear to the reviewer, who also wanted to know how this future work is going to assist the team in evaluating how to complete the project.

Reviewer 4:
Because the project is completing before 2020, the reviewer said it is fair to set 2020 target, but the updated target looking at 2025 has already been released. According to the reviewer, it would have been nice to have a scalability study with this approach taking this into consideration.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented that the project is highly relevant to DOE objectives as the results from this project can provide inputs to selecting a motor that can meet the target.

Reviewer 2:
The reviewer stated that the objective of reducing or eliminating RE material is in line with the DOE objectives.

Reviewer 3:
The reviewer asserted that cost-effective and high-power-density electric motor development is one of the keys for EV penetration into the market.

Reviewer 4:
All development in the project seemed relevant to the reviewer, although some of the approach seems to have been done before.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
It seemed to the reviewer that the team has sufficient resources going forward.

Reviewer 2:
The reviewer stated that the budget seems sufficient assuming multiple prototypes will be built and tested.

Reviewer 3:
It looked to the reviewer that the resources are currently sufficient considering the proposed future research.

Reviewer 4:
The reviewer commented that GM and ORNL have vast resources more than capable of completing the scope.

Presentation Number: elt094
Presentation Title: Development and Demonstration of Medium- and Heavy-Duty Plug-In Hybrid Work Trucks
Principal Investigator: John Petras (Odyne Systems)

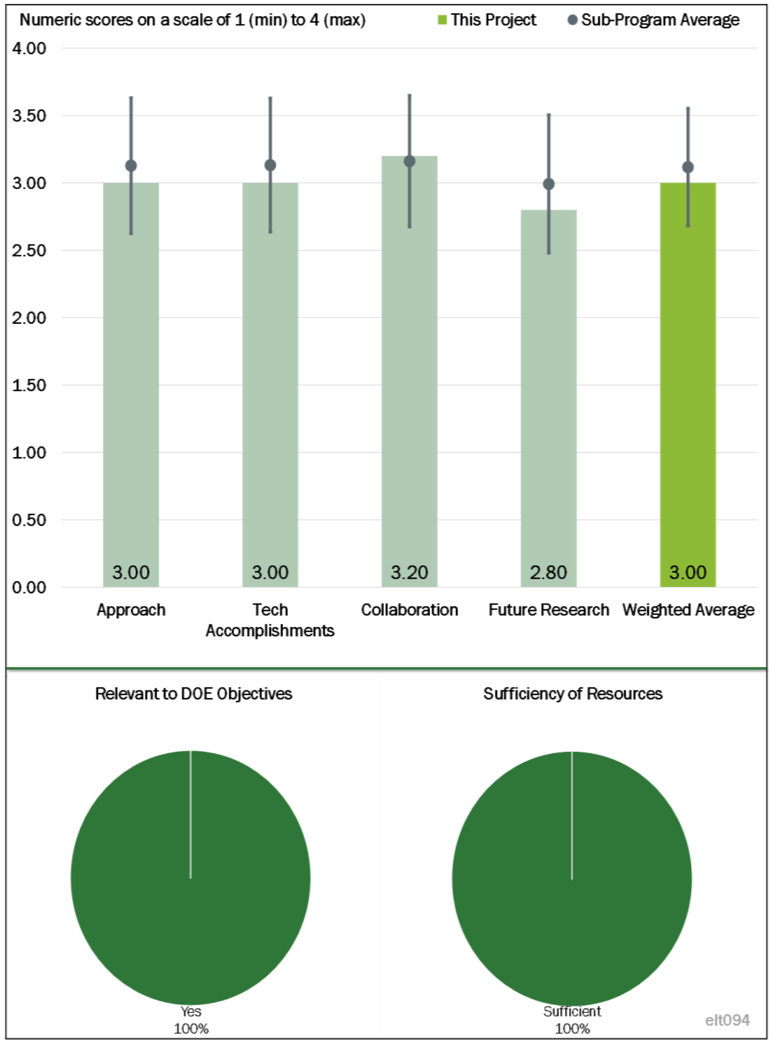

Figure 4-16 - Presentation Number: elt094 Presentation Title: Development and Demonstration of Medium- and Heavy-Duty Plug-In Hybrid Work Trucks Principal Investigator: John Petras (Odyne Systems)

Presenter

John Petras, Odyne Systems

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the overall objective of this project is to develop and demonstrate an advanced PHEV MD to HD work truck with greater than 50% reduction in fuel consumption (compared to a conventional diesel vehicle baseline) with a targeted return on investment (ROI) equal to or less than 5 years. The reviewer listed three phases of the project: the first phase is system design and analysis, the second phase is prototype refinement and verification, and the third phase is vehicle customer deployment and demonstration. According to the reviewer, the primary focus areas are optimization of the powertrain and full vehicle energy use, battery system sourcing and development, and chassis/vehicle/system development and integration.

The reviewer noted that Odyne has adopted a very strong approach to this project. The reviewer pointed out that every work truck function is unique and differs day-by-day; therefore, vehicle configuration is dictated by fleet customers. Odyne’s approach includes a plug-in hybrid propulsion system and work site idle reduction system, which incorporates a modular design that can be applied to multiple OEM chassis and application platforms using the same base hybrid system. The reviewer found the approach to be minimally intrusive where hybrid power is enabled through the existing power-takeoff (PTO) port. No changes are required to the base powertrain and the powertrain warranty from Allison is retained. The reviewer commented that advantages of this approach include applicability to many OEM work truck models, potentially lower costs due to a larger market, launch assist and regenerative braking (more power, better driving efficiency), battery/electric motor support for jobsite functions, and field recharge via the diesel engine if required with no interruption of jobsite function. The approach is based on an optimized PTO-based hybrid system for a real-world truck, full-day duty cycle. The reviewer said that the team is incorporating a number of cost-reduction elements through functional integration and advancements in lithium-ion batteries, power electronics, and up-integration into the vehicle. The project will consolidate components, simplify cooling systems, and optimized ancillary components such as brackets.

Overall, the reviewer found the approach to be very solid and logical, addressing many of the key challenges (including modularity/flexibility, consumer acceptance, cost) to incorporating hybrid electric systems into MD- and HD work trucks, which have been very underserved markets.

Reviewer 2:

The reviewer said that the approach used for project timing, architecture, and project planning is feasible to achieve the scope of the project.

Reviewer 3:

The reviewer suggested that the project team consider including air-conditioning (AC) load power consumption for a more realistic overall fuel economy calculation, and testing the impact of cold and hot temperatures on the overall fuel economy calculation and testing.

Reviewer 4:

There appeared to the reviewer a lack of comprehensive vehicle system and component level modeling that was used to derive hardware and control system requirements that could be subsequently cascaded to sub-tier suppliers for design.

Reviewer 5:

The reviewer really liked the idea of using a stock transmission and stock engine. However, the goal of a 50% reduction in fuel consumption when compared to a conventional diesel vehicle baseline is really so ill-defined that it is subjective. The reviewer commented that there is no specification for a baseline with respect to fuel consumption when the baseline transmission and diesel engine have not been defined. The reviewer wanted to know what year, what model, how many cylinders, what horsepower, and what duty cycle.

According to the reviewer, a shortcoming in the approach is the ROI. No needs analysis was done among fleets that deploy work trucks to establish their desired ROI. The reviewer stated that the trucking industry typical desires an ROI of 2-3 years while the project goal was 5 years. If the project goal is not going to be realistic, the reviewer suggested that it should be dropped.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found progress to be mainly on-track to meet overall project objectives. The team clearly understands the use cases for the utility operators who will be demonstrating this technology.

Reviewer 2:

The reviewer remarked that the propulsion and charging systems are well-defined. The system model, design, and evaluation cycles are clearly selected. The reviewer commented that the lack of a battery supplier and design, if not finalized, is a high risk compared to the other already selected system components (charger, inverter, etc.).

Reviewer 3:

The reviewer said that simulation and dynamometer testing are fine. But, there the project team needs to demonstrate a test plan in cold ambient weather and assess the impact on the battery and overall performance.

Reviewer 4:

The reviewer liked the minimally intrusive hybrid power plus power take-off and modular design applied to an OEM chassis because it is extremely practical and viable. The goal of 50% fuel consumption seems to have been reached for the stationary work truck use but not for the driving fuel economy. According to the reviewer, a shortcoming is that the battery package was not optimized when it should have been optimized early on.

Reviewer 5:

The reviewer reported that the project has clearly established objectives and is on schedule. The project established a solid list of project milestones for BP 1 and 2. Two go/no-go milestones have been set for June 2018 (prototype design freeze) and May 2019 (prototype vehicle performance validation). The reviewer said that it would have been beneficial if the author provided more detail on the specific criteria for satisfying the go/no-go milestones.

A long list of accomplishments has been presented, including the development and evaluation of both in-motion and stationary drive cycles (including a transient PTO stationary duty cycle for dynamometer testing and vehicle full-day simulation, dynamometer testing and results of a Freightliner-Odyne hybrid work truck chassis over multiple drive and stationary cycles, and simulation correlation (greater than 90% across all drive cycles) with dynamometer results. Other accomplishments include development of a full-year fuel-use model to account for daily variations, spec'ing of battery systems requirements and identification of appropriate suppliers, and new component development/integration and test truck and system layout. The reviewer noted that preliminary results show only modest fuel economy improvements in driving mode, but significant improvements in a stationary model. The author indicated significant emissions benefits. The reviewer mentioned that Odyne believes significant further improvements in driving fuel economy can be achieved through improved calibration, drive optimization techniques, and job site/driving balancing algorithms.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the collaboration between team members appears to be well coordinated and ongoing.

Reviewer 2:

The reviewer found the project team to be very strong, incorporating national laboratories, industry at the vehicle and systems levels, a utility, and a municipal entity (South Coast Air Quality Management District [SCAQMD]). The role and function of each team member are clearly defined.

Reviewer 3:

The reviewer commented that the team and collaborations are sufficient and suggested that leveraging some to better understand the utilization of such technology in cold weather environments.

Reviewer 4:

The reviewer stated that roles and responsibilities for each of the involved partner are well-defined except for the charging system.

Reviewer 5:

According to the reviewer, there could have been better collaboration with the actual users, such as fleet owners/operators. There was too much reliance on NREL, which has a lot of theoretical expertise but no hands-on, practical, real-world experience with work trucks. The reviewer said that there should have been a needs analysis done first, followed by a study of business requirements. The reviewer did not see any input from either Sempra or Duke Energy or a fleet owner/operator nor collaboration with an end-user. The reviewer would like to see more emphasis on end-user needs, because the end-user makes or breaks technology deployment. The end-user is critical. The reviewer commented that an interesting end-user to see on this project is a fire engine, such as pumpers, or trucks outfitted with electric arc welding equipment or air compressors.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the project clearly defines remaining challenges and barriers. The proposed future research is clear, logical, and progressive falling squarely into the framework of the overall project objectives, phases, and milestones. The reviewer commented that targets to demonstrate up to 50% improvement in driving-cycle fuel economy are very aggressive given that early results indicate only modest improvements. Analytical demonstration of a 50% reduction in work-truck fuel use is significantly stronger. The reviewer commented that little specific discussion was provided of alternate means to mitigate risk through alternate development pathways.

Reviewer 2:
The reviewer wanted to see cost targets quantified along with baseline costs and reduced system costs.

Reviewer 3:
The reviewer said that staying on schedule to test the demonstration vehicle is critical and asked that testing in cold weather, under maximum electrical loads, and daily charge/discharge to see the impact on the battery SOC is included.

Reviewer 4:
The reviewer pointed out that the decision to focus the technology demonstration on an upfitting design rather than a more integrated approach will allow for rapid deployment of the technology into the fleet with a high level of confidence, but it precludes the opportunity to optimize the design.

Reviewer 5:
The reviewer stated that the author provided no strategy for demonstration/deployment of the five prototype vehicles in Southern California, and asked what duty cycles, what type of work trucks, or what organization would be deploying the vehicles. The reviewer said that the authors did not provide a strategy for solving the problem of too many vehicles returning to base with excess battery energy remaining. The authors did not provide a strategy for approaching the goal of 50% reduction in driving fuel economy. It would have been helpful for the reviewers to hear these strategies and critique them or suggest improvements.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that this project supports the overall DOE objectives of energy reduction because it shows a path to reduced fuel use.

Reviewer 2:
The reviewer responded yes, this project does support DOE objectives to reduce fuel use and emissions from the nation’s transportation sector. Historically, analysis and research for MD and HD commercial vehicles have focused on over-the-road and delivery vehicles. The reviewer stated that this project addresses the fuel consumption (and utility and emissions) of work vehicles, which have been notably underserved through the years.

Reviewer 3:
The reviewer found this project to be in line with DOE’s clean energy plan, which includes expanding to large-size vehicles.

Reviewer 4:
The reviewer noted improved driving fuel economy and system cost.

Reviewer 5:
According to the reviewer, the issue in answering the question of how relevant this particular project is to the overall DOE objectives is as follows: out of the universe of possible areas for reducing fuel consumption or displacing petroleum consumption in trucks, what proportion is affected by improving the fuel economy of work trucks. The reviewer would argue that work trucks do not occupy a very high proportion, probably in the 10%-20% range.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the resources appear to be sufficient to meet the project objectives.

Reviewer 2:
The reviewer mentioned that total project funding is approximately $7 million (30% DOE) with 70% from industry and the Federally Funded Research and Development Centers (FFRDCs). The project is currently on schedule and the available funding seems sufficient to achieve the project objectives and milestones.

Reviewer 3:
The reviewer said that the identified partners hold the proper experience to ensure a successful project.

Reviewer 4:
The reviewer's comment was that careful monitoring was needed to stay on track.

Reviewer 5:
The reviewer thought that resources are more than sufficient. The reviewer did not think that the analytical modeling and other work by NREL or ORNL are all that relevant, necessary, or even important.

Presentation Number: elt095
Presentation Title: Vehicle-to-Grid Electric School Bus Commercialization Project
Principal Investigator: Andy Moore (Blue Bird Corp.)

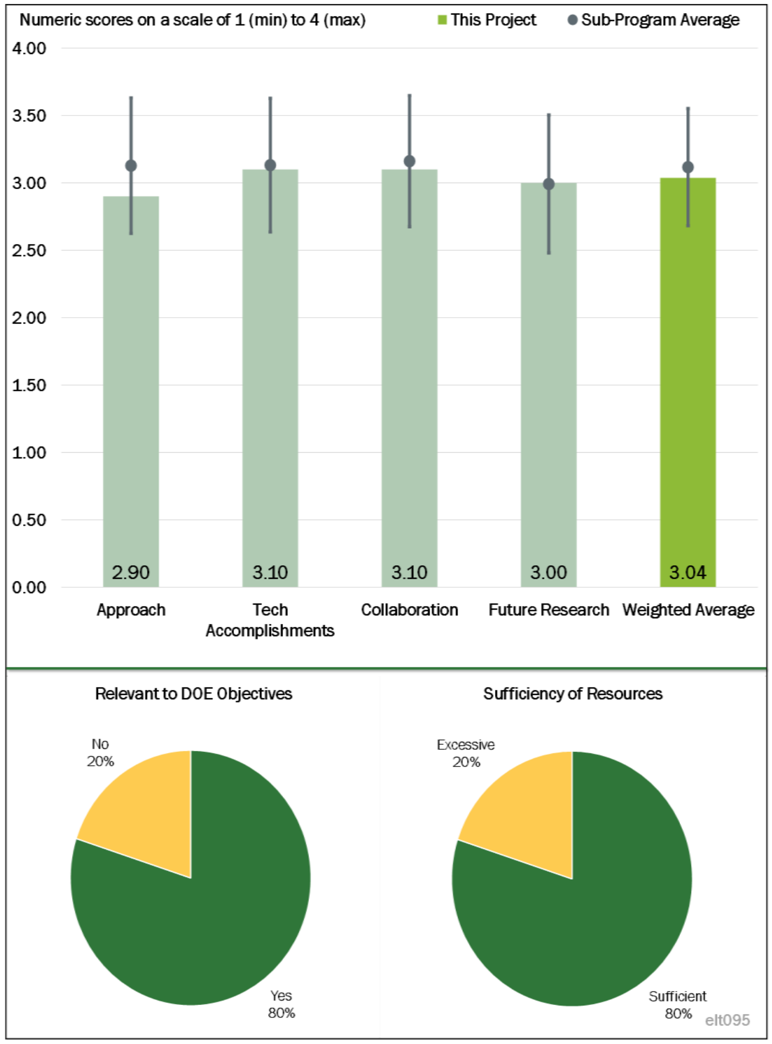

Figure 4-17 - Presentation Number: elt095 Presentation Title: Vehicle-to-Grid Electric School Bus Commercialization Project Principal Investigator: Andy Moore (Blue Bird Corp.)

Presenter
Michael Boggess, Blue Bird Corp.

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer stated that the overall objective for this project is to develop a compelling value proposition for electric school buses based on total cost of ownership including vehicle-to-grid (V2G) and vehicle-to-building services. The project will advance the technical maturity of selected MD, electric drive components to achieve superior energy efficiency and reduced operating costs. According to the reviewer, the underlying philosophy is that a competitive total cost of ownership can be achieved for an electric school bus through optimizing bus capital cost, bus operating cost, and revenue generation from grid integration.

The reviewer noted that the challenges and barriers are clearly defined including achieving an energy efficiency of 1.1 kilowatt-hour (kWh)/mile (with a 100-mile range per charge target), a fully certified 200 kW bidirectional on-board inverter, implementation of the charging system, demonstration of electric buses both as transportation assets and distributed energy resources, and commercialization. In order to achieve performance, safety, and costs comparable to or better than advanced conventional vehicle technologies, the reviewer stated that the approach targets smart design, advanced telematics, integrated thermal management, as well as high-power charge/discharge capability to capture available vehicle-grid synergies. The project is also looking at localized and spot heating and cooling when it is done while charging as opposed to in transit. The reviewer thought that it is especially compelling that the project emphasizes total-cost-of-ownership parameters (e.g., electricity expense, revenue generation), a production version of the V2G bus with "design for marketability," and development of bus financing tools (e.g., battery leasing scheme).

The reviewer observed that the project is well-designed, logical; it is quite feasible it will achieve its objectives without downplaying the fact that a competitive cost of ownership may not be obtained. The reviewer said that a comprehensive listing of milestones (with three go/no-go milestones) including start and end dates is provided.

Reviewer 2:

The reviewer stated that the approach used for architecture, type of components selected, simulation, and test plan seems to be good. The critical concern is with the battery source selection, size, and performance.

Reviewer 3:

The reviewer noted that the advantages in charging cost are not clear. Employing a 200 kW on-board inverter over a lighter and more cost efficient, one-way charger is not made clear.

Reviewer 4:

The reviewer said that the overall approach to electrification of school bus fleets is good, but the powertrain architecture selection and the concept of leasing batteries and selling excess power on the grid does not make sense, especially given the high utilization rates. It was unclear to the reviewer how this plan would work to incentivize school districts to capitalize for these systems.

Reviewer 5:

The reviewer commented that there are a number of issues that have to be addressed that are indirectly related to the value proposition for a HD, battery-electric school bus that have nothing to do with the electric drive system or the vehicle-grid integration. The reviewer opined that there is a need to improve the heating/air-conditioning ventilation system efficiency and thermal management system to reduce the demand for electricity. Nothing was mentioned about leveraging the results of the DOE SuperTruck program (in particular, “CoolCab”) for heating/cooling the inside of the school bus. The reviewer suggested that there is also a need to reduce the weight of the school bus and its equipment. Again, nothing was mentioned about leveraging the results of the DOE SuperTruck program with respect to weight reduction.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Overall, the technical progress seems on track to the plan laid out according to the reviewer.

Reviewer 2:

The reviewer found that the project has demonstrated a number of solid technical accomplishments. Blue Bird has identified direct-drive architecture (single speed) as having the highest energy efficiency across three different duty cycles. The project identified the range of rear axle ratios, meeting standing start on a grade of 20% and a top speed of 65 mph. The team chose the TM4 Suno traction motor based on its low-speed torque performance. The reviewer commented that the bus’s thermal management system has been modeled and designed representing the best tradeoff between optimizing thermal energy recovery, cost, and complexity. Blue Bird and Efficient Drivetrains, Inc., have built and benchmarked the first prototype bus, “P1.” The reviewer noted that NREL has collected detailed duty-cycle data on buses from the Rialto School District and combined those data with the NREL FleetDNA data to select a representative drive cycle for powertrain development and vehicle efficiency testing. Prototype electric bus P1’s energy efficiency has been benchmarked at 1.53 kWh/mile in NREL’s REFUEL dynamometer using the NREL duty cycle derived from approximately 1,000 hours of school bus operating data. The “pre-improvement” benchmark will be what subsequent prototypes will be measured against. The reviewer said that the project may be a little behind schedule.

Reviewer 3:

The reviewer said that a cost-benefit analysis is not presented to support the objective of “income-generating grid integration.”

Reviewer 4:

The reviewer remarked that the technical accomplishment is limited to analysis and dynamometer testing, based on limited metrics for battery/EV range performance. There is a need to include real-world metrics showing the performance of a school bus under worst-case operation, according to the reviewer.

Reviewer 5:

The reviewer did not have a good feeling that either the electric energy storage system (batteries) or the power electronics (power management system) were optimized. There was no discussion of either system, which are critical to optimizing the kWh/mile fuel economy. The reviewer noted that there was no justification (trade-off studies and comparisons) for whatever system was selected.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that the project incorporates a multi-disciplinary project team and supportive group of stakeholders. The team is strong and diverse with what appears to be the right balance of industry, a national laboratory, a utility, university, school districts, and state government. The reviewer stated that no notable omissions have been identified.

Reviewer 2:

The reviewer stated that there appears to be sufficient interaction among the team members.

Reviewer 3:

The reviewer said that there was a multi-disciplinary team.

Reviewer 4:

The reviewer commented that coordination among the stakeholders was acceptable.

Reviewer 5:

According to the reviewer, what was lacking was a broader perspective of electric vehicles in general, especially in terms of demonstration/deployment. While SCAQMD was the project partner that dictated the selection of the Rialto Unified School District (Rialto USD) for technology demonstration/deployment, the reviewer saw this selection as myopic because if the project partners had looked at the big picture, they would have seen that Foothill Transit in the adjacent area (San Gabriel Valley), is skeptical about deploying any more electric buses because of their high kWh cost. Foothill Transit is paying more than $0.17 per kWh, and this charge needs to be reduced to almost half in order for the fuel charge to be comparable to diesel or natural gas. The reviewer noted that it would not be good for this project to have a successful demonstration but a failed adoption because of high electric cost by the beneficiary. There is no clear driver (i.e., reason), the reviewer opined, for electric school buses in sparsely populated, suburbanized Rialto as compared to a much more densely populated, urbanized area where parents and citizens are concerned about vehicle emissions.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer stated that the proposed future research clearly identifies the technology improvements to pursue for the remainder of FY 2018, including thermal management, telematics/drive parameters, high power inverter, and incorporating improvements to EV bus prototypes P1 and P4. The reviewer noted that a very clear go/no-go milestone (M4) is identified at the end of the first quarter of FY 2019 with a target of closing 50% of the gap between the P1 benchmark (1.53 kWh/mile) and the project target of 1.10 kWh/mile. This go/no-go milestone is very notable for its clarity and definition. The reviewer stated that proposed research for

FY 2019 is to assess results of P3 and P4 energy evaluations and identify areas where further technology improvement can achieve big payoffs. This includes refinements to the drivetrain control system, aggressive lightweighting, and reduction in power circuitry energy losses. The reviewer said that the certification phase for the high-power inverter will be initiated. According to the reviewer, the next two quarters are critical to determining the success of the project. Nonetheless, the reviewer opined that it is notable that Blue Bird intends to go to market with an electric school bus that embodies the best possible set of tradeoffs even if there is no guarantee that a competitive total-cost-of-ownership is achieved.

Reviewer 2:

The project tackles all aspect of proposed approach.

Reviewer 3:

The reviewer posited that there needs to be a comprehensive test plan for real-world and worst-case usage.

Reviewer 4:

The reviewer remarked that the future project research does not address key state and federal certification issues or specifically address key cost barriers to adoption.

Reviewer 5:

The reviewer remarked that the PI failed to present any future strategies for achieving the project target of 1.10 kWh/mile from its present status of the P1 benchmark at 1.53 kWh/mile. Considerable, more likely substantial, improvements have to be made to thermal management; heating, ventilation, and air conditioning efficiency; and weight reduction, let alone whether the rechargeable energy storage system and power electronics (power management) system can be or have been optimized.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

Because this project’s objectives are to reduce fuel use, the reviewer stated that it aligns with DOE objectives.

Reviewer 2:

The reviewer pronounced the project to be directly relevant to barriers identified in VTO roadmaps, especially mutually beneficial vehicle-grid integration arrangements that can lead to competitive total-cost-of-ownership and widespread deployment. The reviewer opined that deployment of electric school buses will reduce the nation’s petroleum consumption and help achieve better air quality for the nation’s school children.

Reviewer 3:

The transportation efficiency improvement and reduced operating cost are relevant, according to the reviewer.

Reviewer 4:

The reviewer said that the project is in line with DOE objectives.

Reviewer 5:

The reviewer commented that the PI already admitted that the PI’s company was already commercializing electric school buses that did not meet DOE goals. If these commercialized electric school buses were successful, it is not clear to the reviewer why DOE objectives are important or relevant. Perhaps the DOE objectives are too stringent, and the end-user, that is school districts, does not care about having school buses that meet the DOE objectives. The reviewer thought that DOE would be better off looking at improving the specific components that make up the electric school bus and leveraging the results of the DOE SuperTruck program. The reviewer thought funding a project of this level of commercialization was questionable.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

Resources appeared to be sufficient to the reviewer to meet overall project tasks.

Reviewer 2:

The reviewer pointed out that this is a large project at roughly $10 million (government and industry total) over 4 years. It is 50% cost-shared. Given the project objectives and scope, the budget seemed appropriate to the reviewer and sufficient to achieve the stated milestones in a timely manner.

Reviewer 3:

The reviewer said that there are multiple organizations with established disciplines and resources

Reviewer 4:

The reviewer noted that barriers and challenges are making the project timing critical.

Reviewer 5:

The reviewer thought that $6.9 million is too much to spend on improving an electric school bus. The budget breakdown for the project was not presented, but perhaps too much funding is going towards modeling, analytical work, and telematics that are not productive or contributing in a cost/beneficial way to improvements in the kWh/mile of the electric school bus.

Presentation Number: elt115
Presentation Title: Zero-Emission Drayage Truck Demonstration (ZECT I)
Principal Investigator: Phil Barroca (SCAQMD)

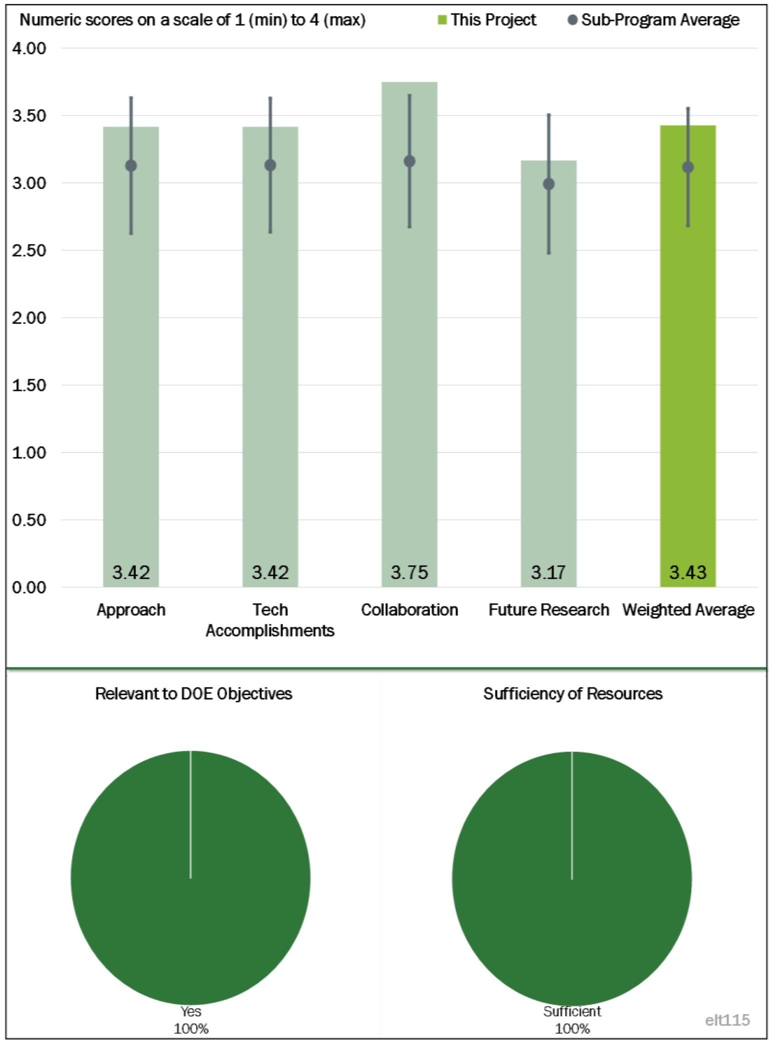

Figure 4-18 - Presentation Number: elt115 Presentation Title: Zero-Emission Drayage Truck Demonstration (ZECT I) Principal Investigator: Phil Barroca (SCAQMD)

Presenter
Phil Barroca, SCAQMD

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer stated that the quality of the work in designing, building, and testing a varied set of vehicles is impressive. The reviewer expressed the hope that the analysis work will reach the same standard, so that fleets looking to add new technology vehicles will be able to tell which best fit their needs, are energy efficient, and make economic sense.

Reviewer 2:
In the reviewer's opinion, it was a great approach to a complicated task.

Reviewer 3:
The reviewer stated that it is nice to see a project that is building, testing, and comparing multiple solutions on similar routes, as it helps to communicate the best technology for differing duty cycles. The reviewer commented that this is always a key to successful deployment of technical solutions.

Reviewer 4:
The reviewer stated that it was a good plan for highly complex project deliveries, but that the objectives need to be expanded for more definition; i.e., the data collection and analysis objective should explain what type of analysis will be performed on the data collected.

Reviewer 5:
The reviewer noted that there were four vehicle technologies and platforms for cross evaluation.

Reviewer 6:
The reviewer stated that the approach to performing the study did not take advantage of the difference in the number of motors for the battery-electric trucks (BETs), or the difference in parallel versus series hybrid for the plug-in hybrid electric trucks (PHETs). The reviewer further commented that it would have been

interesting to see if single versus dual motors makes a difference in application to duty cycle or type of drayage. Similarly, the reviewer stated that it would have been interesting to see if parallel versus series makes a difference in application to duty cycle or type of drayage. The reviewer stated that it was clear that the difference in the application of BETs versus PHET trucks was range, and relief of range anxiety.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that not only has the team built the vehicles, there have been several updates and improvements along the way, especially in the battery systems. The reviewer also found that it is impressive that so many miles of operation have been accrued by the trucks.

Reviewer 2:

The reviewer observed good progress towards the plan, especially given some of the vehicle and infrastructure challenges.

Reviewer 3:

The reviewer noted that the project team completed vehicle builds, and most data collection and analysis.

Reviewer 4:

The reviewer commented that there was a need to complete the data collection on new powered units and obtain weight per load.

Reviewer 5:

The reviewer commented that the team persevered through significant issues over this long timeframe. The reviewer further noted that this now 6-year project is dealing with the real-world improvement of battery performance and had to upgrade vehicles with new battery packs, and deal with a partner leaving the program. The reviewer stated that there was a lack of solid performance tracking of the trucks.

Reviewer 6:

The reviewer commented that the results comparing BETs and plug-in hybrid trucks to diesel as a baseline were good; however, it would have been better to see if there was a difference in freeway speed or fuel economy on freeways as a result of the difference in number of motors or parallel versus series mode of hybrid. The reviewer stated that parallel hybrids work best on over-the-road motorcoaches while series hybrids work best in urban city transit buses. The reviewer observed that it would seem to make sense to see if the same applies to trucks—to see if parallel hybrids work better on drayage trucks that travel to farther-out distribution centers while series hybrids work better on drayage trucks that stay within a few miles of the ports.

Nevertheless, the reviewer expressed extreme disappointment that the team collected absolutely no data on the Transpower PHET with the compressed natural gas (CNG) auxiliary power unit. The reviewer noted that it would have been interesting to see how that compares with its LNG analog, and it would have provided a more robust comparison of the two PHETs with the two battery electric trucks (BETs) rather than one PHET with the two BETs.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that collaboration and coordination amongst parties appears quite strong, and stated that Transpower and US Hybrids view these programs as business development for their companies and understand how to deliver on these types of programs. The reviewer stated that the project was well done.

Reviewer 2:
The reviewer found the project to be successful, considering it was near completion status.

Reviewer 3:
The reviewer commented that it was a great team for the project, and all the bases were covered.

Reviewer 4:
The reviewer stated that, in terms of coordination and cooperation, end-user and fueling infrastructure are important, and expressed the view that, of the two, the most important is the end-user, that is, the fleet owner/operators deploying the prototype trucks, while second is the fueling infrastructure: The reviewer has personally visited the Ports of Los Angeles and Long Beach and is familiar with the natural gas fueling facility—the largest in operation in the United States. Going back to end-users, the reviewer expressed the view that they are excellent in the extent of their cooperation, especially in the area of new alternative fuel technologies.

Reviewer 5:
The reviewer commented that just getting the trucks built required cooperation across the project team, and that operation and updates increased the level required, with no major problems reported.

Reviewer 6:
The reviewer noted that there was good collaboration among the partners to replace the vehicle manufacturer and solve infrastructure fueling issues.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the research needs to continue with new powered units.

Reviewer 2:
The reviewer expressed a desire to see how the CNG PHET performed if run in electric mode, i.e., not kept at a constant SOC, which might be somewhat of a handicap. The reviewer also indicated a desire to see trucks running closer to their all-electric ranges, as well as some economics. The reviewer remarked that the proposed work covers most other questions that must be addressed.

Reviewer 3:
The reviewer stated that a qualitative list of challenges and needs for the future were listed and discussed.

Reviewer 4:
The reviewer expressed the view that the charging time reduction objective should have considered all charging technologies, such as available and standardized DC charging, which would help substantially with charging time reduction compared to alternating current (AC)/DC charging.

Reviewer 5:
The reviewer commented that it was not clear where future research will be heading on these technologies, but that California and the U.S. federal government seem committed to helping advance zero emission electric vehicles (EVs).

Reviewer 6:
The reviewer stated that there does not seem to be an organized, logical, coherent plan for future research, and that the plan seems to be to try different batteries—upgrades—and see what happens as data are collected.

The reviewer found the demonstration of range to be disappointing; there was no attempt to go more than a daily average of 43.81 miles for the BETs when their listed range was 75-100 miles, while the daily average range was 34.45 miles for the PHET, and its listed range was greater than 250 miles. The reviewer found it ironic that the average daily range for the plug-in hybrid trucks was LESS than that for the BETs, when the listed or expected range of plug-in hybrids is MORE than that for battery-electrics. The reviewer expressed the view that future plans need to do something with demonstrating range and testing range with differences in types of powertrain—battery-electric versus plug-in hybrid electric. The reviewer commented that range anxiety is a critical issue with fleets and drivers

The reviewer suggested planning to see what technology works best in what application or drive cycle, and stated that there needs to be some thought about seeing which type of motor—single or dual—makes a difference in deployment, and which type of hybrid—parallel or series—makes a difference in deployment.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer found that the project supports the overall DOE objectives, due to the wide variety of technology solutions meant to demonstrate emissions reductions.

Reviewer 2:
The reviewer noted that this project does support DOE objectives. The reviewer stated that it should be clear that determining what type of power source, powertrain, number of motors, type of hybrid, and configuration makes the best use of energy in the type of deployment—application and drive cycle—is in line with the overall objective of maximizing energy efficiency and petroleum displacement.

Reviewer 3:
The reviewer stated that the project reduced HD vehicle emissions.

Reviewer 4:
The reviewer commented that the project will reduce fuel usage and emissions.

Reviewer 5:
The reviewer stated that, with the exception of CNG—assumed from biogas—the project will deliver viable trucks that use no petroleum, in keeping with a key DOE goal.

Reviewer 6:
The reviewer commented that there are significant barriers to zero emission trucks, and progress may not be made without DOE funding.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer found the project to be successful, considering it was near completion status.

Reviewer 2:
The reviewer stated that the main expense for this project was building custom trucks, and that the team did a good job of designing a set of vehicles that they could afford to build and test.

Reviewer 3:
The reviewer noted that the program is closing in a few months, and that the resources are in place to finish.

Reviewer 4:

The reviewer stated that retrofitting tractors with different types of energy technologies, especially fuel cell range extenders, is extremely challenging because it is custom-tailored work requiring labor intensive effort.

Reviewer 5:

The reviewer indicated that the project can use more funding and cooperation from the port on load data, such as weight.

Presentation Number: elt116
Presentation Title: Zero-Emission Delivery Vehicle Deployment
Principal Investigator: Andrew DeCandis (Houston-Galveston Area Council)

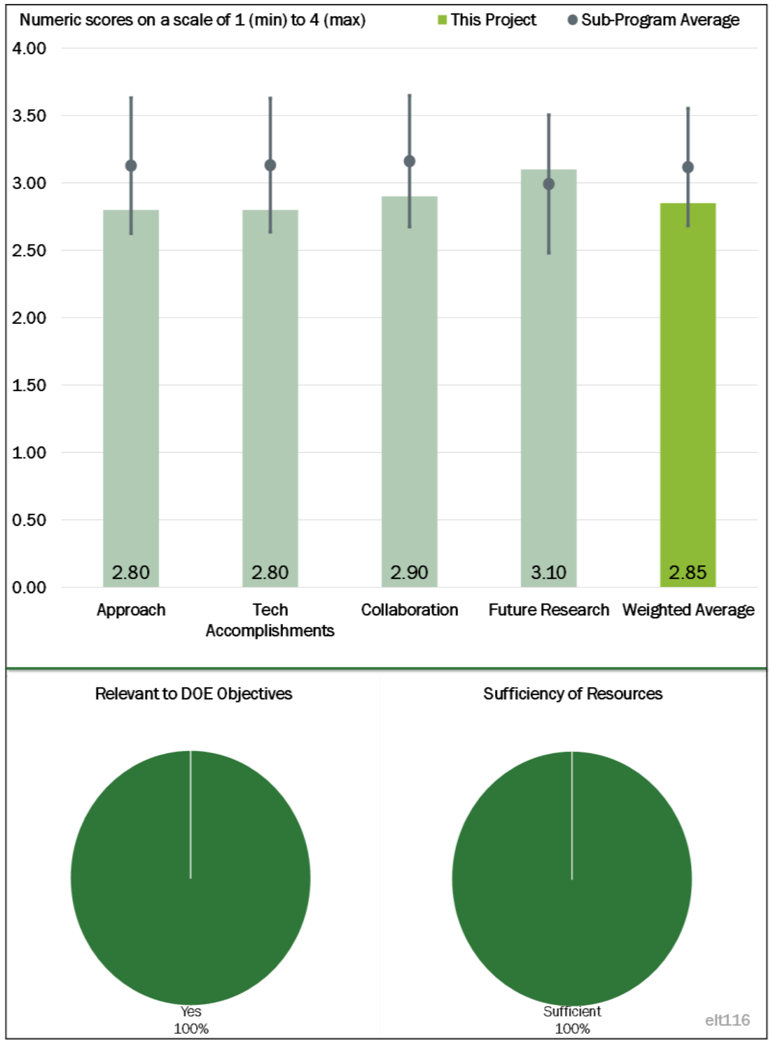

Figure 4-19 - Presentation Number: elt116 Presentation Title: Zero-Emission Delivery Vehicle Deployment Principal Investigator: Andrew DeCandis (Houston-Galveston Area Council)

Presenter

Andrew DeCandis, Houston-Galveston Area Council

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to this reviewer, the project was well-conceived and has helped to address significant technical and logistical questions.

Reviewer 2:

The reviewer commented that the approach was very good in that it was always focused on putting advanced vehicles into the hands of real-world users (UPS), to determine technology readiness. The reviewer further stated that the team correctly identified fleet acceptance (reliability) as a critical factor, and that, ultimately, the project team had to be flexible as it ran into issues with vehicle costs, suppliers, fleet acceptance, and the experimental nature of the vehicles. When issues arose, the team ultimately did adjust to ensure that project needs were met. The reviewer stated that, perhaps above all else, the single most important approach element was the selection of a committed fleet partner.

Reviewer 3:

The reviewer observed that identified barriers included the high cost of low-volume EV trucks, fleet acceptance of the vehicles, and uncertainty in production capabilities and timeline, particularly for experimental vehicles. The reviewer noted that project funding to pay for these vehicles addressed the cost barrier in the short term, but said that it would have been nice to see something on how this project approach helps to address cost barriers in the long term. The reviewer commented that the project’s placement of vehicles for use by fleets is a reasonable approach to address the fleet acceptance barrier, but pointed out that, as the presenter acknowledged, having some performance, reliability, or up-time incentives in the contract with the manufacturer would have been an improvement on the approach. The reviewer further stated that, with the benefit of hindsight, the early approach of the project could have been improved through selecting a different manufacturer partner from the outset, but the ongoing approach to monitoring the performance and utilization of vehicles in the fleets alongside comparable conventional vehicle operation is good.

Reviewer 4:

The reviewer stated that deploying new technology in the real world is important to customer satisfaction during adoption. The reviewer commented that the approach here was strong, and that support for new technology doing real freight movement is generally underappreciated. The reviewer concluded, however, that 36% uptime is not acceptable, even for something this far in the future, to get fleets to want to participate in these programs in the future.

Reviewer 5:

The reviewer stated that the largest issue with this work was the lack of support for the vehicles in case of failures, which were numerous. The reviewer added that, although some miles were accumulated, the decreasing mileage due to component failures could not be addressed, and most regions showed little mileage accumulation. The reviewer commented that there was insufficient planning for vehicle support in the project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the team overcame a number of issues earlier in the project, but, at the same time, there have been operational issues with both hardware and software, now that the vehicles are in use, resulting in significant down-time. The reviewer observed that Workhorse has been modifying the vehicles, but the units are being used by UPS to deliver packages, and overall utilization to date is 36%, although the trend is heading down. The reviewer commented that some vehicles have reached nearly 98 miles in a day, with an average trip length of 49 miles. The reviewer stated that it should be noted that the EVs do demonstrate significant cost savings—1/3 of the operational cost of diesels—while demonstrating major greenhouse gas reductions.

In this reviewer's opinion, the issues that arose, and the solutions developed, have helped the vehicle manufacturer to improve its product, particularly where hardware selection is concerned. The reviewer commented that, most importantly, despite technical issues with the Workhorse product, UPS has agreed to buy many more to operate in its fleet. The reviewer concluded that the information and experience developed under this project is assumed to have helped UPS build the confidence it needed to make that decision.

Reviewer 2:

The reviewer commented that progress was good, but utilization rates continue to be low, which limits the amount of data.

Reviewer 3:

The reviewer noted that this program is ending, and stated that the low utilization makes for this to be a tough grade, but the trucks did remain in service with many fixes.

Reviewer 4:

The reviewer observed that mileage was collected, but the overall fleet numbers were low. The reviewer noted that the plan was to have utilization near capacity for these vehicles; however, reliability issues with vehicles and chargers greatly reduced utilization to a fraction of what was intended.

Reviewer 5:

The reviewer commented that the vehicles are deployed and operating in the UPS fleets, but it is unfortunate that they have been plagued by reliability problems and have had such low utilization rates. The reviewer stated that, based on this, it would seem that the project has had the opposite of the desired result, which was to build local fleet acceptance and confidence in the new technology. The presenter indicated that UPS is nonetheless doubling down on EV evaluations in multiple fleet locations and feels that the technology is progressing in the right direction, so the reviewer considered this to be a positive outcome, if these improvements are indeed occurring. The reviewer hoped that the fleets see better reliability going forward. The results indicated that the vehicles are able to satisfy the vehicle range requirements when they are able to operate, and that the energy costs are significantly lower per mile driven than for the conventional version of the vehicles; however, the reviewer found that a clear pathway was not shown for getting the capital and maintenance costs into a competitive range with the incumbent technology.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer observed that the project team appears now to be working closely with Workhorse to resolve issues, and UPS has stood by the project throughout, despite the operational problems. The reviewer expressed the opinion that having a strong user partner like UPS has been critical for this project, and remains critical to ensuring ultimate deployment by industry.

Reviewer 2:

In the reviewer's opinion, the team seemed to work well together.

Reviewer 3:

The reviewer observed that collaboration seems good, but could have been improved, which would have improved utilization.

Reviewer 4:

The reviewer stated that the Center for Transportation and the Environment is leading the data collection for the project, and seems to be working effectively with UPS to collect data on the performance of the vehicles and reporting these data to the prime (HGAC). In the reviewer's opinion, the OEM partner, Workhorse, could be more effective at providing service support to improve up-time for the vehicles in the UPS fleets.

Reviewer 5:

The reviewer stated that insufficient planning for support of the vehicles was apparent; however, this serves as a good educational moment for implementing new technologies into fleet settings.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer expressed the view that this project, and its reporting over the years, has helped EV developers, and developers of EV components, such as batteries, to bring better, more reliable products to the marketplace. The reviewer stated that these sorts of projects help bring to the surface issues related to temperature, weather, driver interactions, dirt and grime, roads, etc., that occur in the real world, and that manufacturers often are not aware of.

Reviewer 2:

The reviewer observed that the project is winding down, with the demonstration to end in November 2018, so there is not that much left to do, but completing the demonstration period and compiling results is important for future potential adopters of the technology, as well as Workhorse itself.

Reviewer 3:

The reviewer noted that continuing the data collection and analysis are the only remaining tasks, but that these are critical to determining the overall conclusions to be drawn for local delivery fleet operators.

Reviewer 4:
In the reviewer's opinion, at this point in the project, focus on continued in-service evaluation of the deployed vehicles and, to the extent possible, maximizing their up-time seems like the correct focus for continued work, and is likely all that is practical with the remaining budget. The reviewer stated that exact numbers were not given, but interpreted the current expenditure level to be indicative of the available project burn rate through the end of the project.

Reviewer 5:
The reviewer commented that it is not clear how the fleet operators are going to work with the vehicle providers to overcome the parts and charging failures to increase reliability and utilization of the vehicles in the fleet.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted that the project is focused on deployment of electric trucks to displace petroleum, which is fully in line with DOE objectives.

Reviewer 2:
The reviewer found that this project's objectives explore reduction in fuel use and energy consumption, which is a key DOE objective.

Reviewer 3:
The reviewer stated that early detection of issues not found in laboratories is very helpful.

Reviewer 4:
The reviewer commented that, although there are a number of issues with getting these vehicles to a high utilization rate, some data have been collected to demonstrate the reduction in petroleum use as well as the calculated reduction in carbon dioxide (CO_2) emissions.

Reviewer 5:
The reviewer stated that improving the state of the art for electrified delivery vehicles is relevant for DOE objectives to diversify transportation fuel sources and decrease energy costs for fleets. The reviewer also commented that it is at least mildly disheartening that the current project suggests there is still a pretty long way to go to realize these benefits.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed that funding appears sufficient, and the project is ending soon.

Reviewer 2:
In the reviewer's opinion, the resources being spent currently and over the last couple of years—approximately 1%-2% of the original project budget—seem sufficient for monitoring of the vehicles through the end of the project period of performance.

Reviewer 3:
The reviewer stated that the project resources appear sufficient to complete the project.

Reviewer 4:
The reviewer noted that the program is ending.

Reviewer 5:

The reviewer stated that sufficient resources were provided, and that issues were associated with parts failures.

Presentation Number: elt158
Presentation Title: Zero-Emission Cargo Transport II: San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project
Principal Investigator: Joseph Impullitti (SCAQMD)

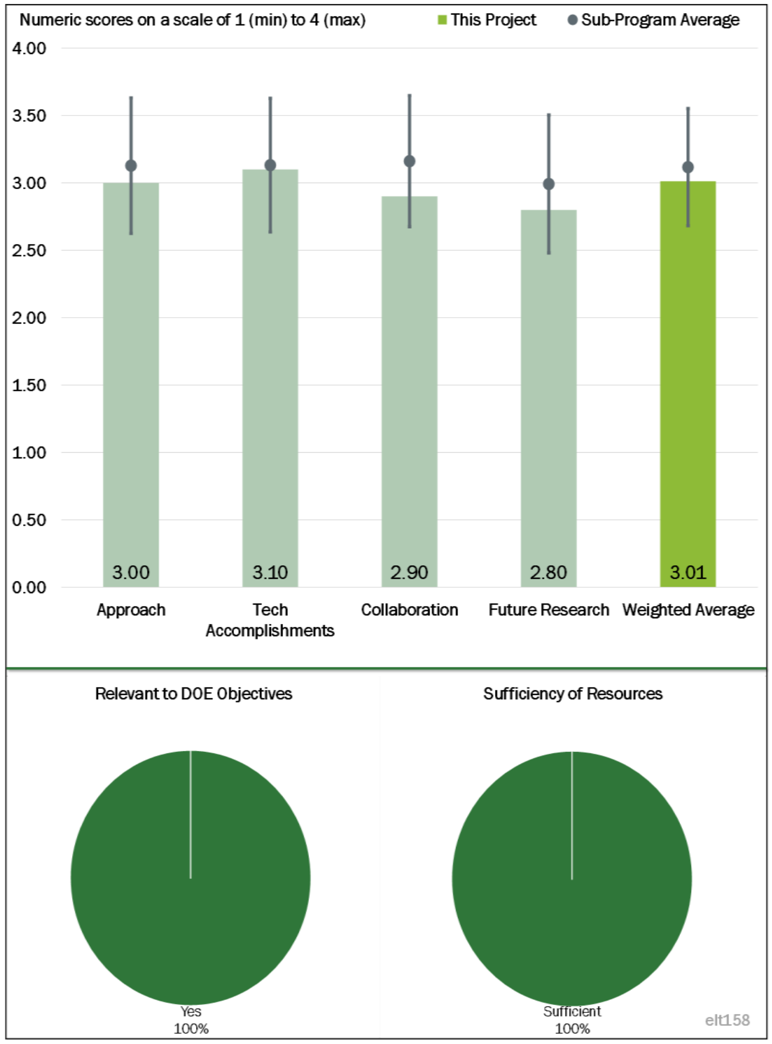

Figure 4-20 - Presentation Number: elt158 Presentation Title: Zero-Emission Cargo Transport II: San Pedro Bay Ports Hybrid & Fuel-Cell Electric Vehicle Project Principal Investigator: Joseph Impullitti (SCAQMD

Presenter

Joseph Impullitti, SCAQMD

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that a number of vehicle technologies are being evaluated in demonstrating zero emission drayage utilization, and stated that the variety in designs should yield insight into benefits and issues associated with each technology.

Reviewer 2:

The reviewer commented that this is quite a big project, with $20 million in funds, and that evaluating various technologies in the same drayage application is good. The reviewer saw this project as a simple way to evaluate the technologies.

Reviewer 3:

The reviewer noted that the presentation did not include specific “approach” slides, but that it can be inferred that the approach is to try out a number of different alternative vehicle configurations and evaluate which seem to have the best maturity and promise for reducing emissions and diesel consumption by drayage trucks. The reviewer observed that, over the past year, the approach seems to have focused on efforts by the contractors to complete their design and build work on the vehicles and to conduct their own testing, and in some cases the vehicles have started deployed service at the ports.

Going forward, the reviewer assumed that the approach will shift to evaluating the zero-emission cargo transport (ZECT) vehicles’ performance against comparable conventional vehicle performance in drayage operation. In the reviewer’s opinion, these steps seem appropriate to achieve the project goals. The presenter stated that a formal total cost of ownership analysis is not part of this project, but that CALSTART is taking a look at that. The reviewer indicated that it would be nice to have that or a similar adoption analysis conducted as part of this specific project, to evaluate not only impacts from different levels of potential vehicle adoption, which is mentioned at the end of the presentation, but also what might be required to achieve the various penetration levels—such as cost reductions for the advanced vehicle technologies, diesel price levels that would result in a positive total cost of ownership calculation, overcoming any performance limitations relative to conventional drayage vehicles, considering any limitations on the number of use cases where owners would be comfortable replacing conventional trucks with these alternative powertrain options, and/or the need for or impact of emissions regulations near the ports if that would end up being the primary driver for adoption.

Reviewer 4:

The reviewer commented that the goal of building and testing hydrogen fuel cell tractors is laudable, although there were many challenges and also some setbacks. In the reviewer's opinion, there needs to be both applied and basic research and development on the use of hydrogen propulsion for trucks, even though it has been done for transit buses. The reviewer stated that it is not clear why a CNG hybrid tractor was included in this project, for it does not involve fuel cells—as the title of the project would imply—and CNG hybrid technology has already been commercialized. The reviewer cited as an example the CNG hybrid transit buses running on the 16th Street Mall in downtown Denver, Colorado.

Reviewer 5:

The reviewer stated that this work does a good job on the building and demonstration of novel vehicle types, but the reviewer was unconvinced that the choice of vehicles is representative of those that will be most efficient and economical in actual operation. The reviewer stated that it will be very important in the analysis phase to compare the vehicles to each other and to other vehicle types, for different types of routes and usage, and, in particular, it would be useful to compare vehicles that use the available biogas directly with those using hydrogen from biogas.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the technical accomplishments over the past year of performance included hydrogen fueling infrastructure installation for use by the vehicles. In addition, progress was reported by each of the manufacturers on building and testing the vehicles and certifying them for deployment at the ports. The reviewer noted that in all cases the presenter reported good progress. The reviewer observed that barriers were identified through the course of the hydrogen infrastructure installation, including the preclusion of a permanent hydrogen station installation, but the use of portable hydrogen dispensing appears to be adequate to satisfy the fueling needs of these vehicles.

According to the reviewer, one open question will be whether the hydrogen vehicles' range will be limited by round trip driving distances—if they are in practice limited to only refueling at these portable hydrogen fueling installations—which will place them at a relative disadvantage to conventional vehicles that may travel farther and refuel away from the port. With respect to the vehicle builds and testing, the reviewer commented that nearly all of the vehicle designs appear to be complete, with testing well underway or completed, and the replacement contractor for the fuel cell range extended drayage truck was reported to be making good progress. The reviewer noted that, according to the presenter, manufacturers apply rigorous criteria—BAE/Kenworth was specifically mentioned as requiring five consecutive days of faultless operation in closed course testing—before releasing the advanced technology vehicles into the field. The reviewer commented that this is prudent to minimize the potential for performance problems that would leave the drayage operators with a negative perception of the advanced technology vehicles' capability and reliability.

Reviewer 2:

The reviewer indicated that progress is what would normally be expected on a project of this type involving the fabrication of prototypes, and added that there are many unanticipated challenges and upsets.

Reviewer 3:
The reviewer noted that the objective of completing the vehicles and beginning testing in 2017-2018 has begun and some data are being collected, and added that, although not all of the vehicles were completed, it appears they are due shortly and should begin testing within the timeframe set.

Reviewer 4:
The reviewer commented that it is unfortunate that one of the three players needed to withdraw. The reviewer remarked on the excellent accomplishments, with respect to setting up fueling stations and other infrastructure support for these demonstrations.

Reviewer 5:
The reviewer stated that progress is very good, in spite of glitches like not leaving enough room for the power module. The reviewer commented that perhaps the thermal management issue could also have been foreseen.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer commented that strong collaboration is evident, and that the companies understand how this co-funded work is crucial to their startups and adoption opportunities.

Reviewer 2:
The reviewer stated that the degree to which disparate systems are being successfully mated is impressive.

Reviewer 3:
The reviewer commented that there was not a specific collaboration and coordination slide, but clearly multiple contractors are involved in building the trucks; various providers and agencies were involved in getting the portable hydrogen stations in place; and, presumably, the ports and fleet operators are coordinated to operate the vehicles in-service. The reviewer noted that it was not clear how data collection, analysis, and performance reporting will be conducted over the coming year, but expressed hope that this will be well coordinated and will give a good picture of how the vehicles are performing relative to conventional drayage vehicles.

Reviewer 4:
The reviewer observed that the presentation failed to list the end-users who will be testing the prototype hydrogen fuel cell trucks at the Ports of Los Angeles and Long Beach, and expressed hope that TTSI and members of the Harbor Trucking Association are involved, or are at least offered an opportunity to volunteer in testing. The reviewer has found TTSI eager and willing to try new alternative fuel technologies.

Reviewer 5:
The reviewer commented that support across the technical and engineering side of the vehicle development appears to be good and sufficient; however, coordination with the hydrogen supply side—permitting, etc.—remains a barrier.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the future research that is planned to better detail the business case and commercialization rollout by CALSTART will significantly help long term adoption.

Reviewer 2:

The reviewer stated that it will be very important to do a complete economic analysis for the various truck types, and to compare the results to those for other configurations and operating modes, including ones that use batteries and other more conventional technology combinations. The reviewer commented that, even if the demonstration trucks operate efficiently, they may be much more expensive than other types that are as efficient, or nearly so.

Reviewer 3:

The reviewer stated that future work for the project will evidently include completing the build, testing, and deployment of those vehicles that have yet to do so, along with use, data collection and evaluation of the vehicles in drayage service. The reviewer noted that one of the identified barriers for the proposed technology is fueling infrastructure availability and location. The presentation indicated that the South Coast Air Quality Management District (SCAQMD) is working with others toward permanent fueling stations, but that this will be a challenge. The reviewer indicated that, for this specific project, it seemed the temporary stations should suffice.

The reviewer commented that the presentation identified “System Integration: Safe and efficient deployment of the technology” as another barrier that the project should help to address, through integration and deployment of a variety of different ZECT vehicle designs. With respect to the cost barrier—for fuel cells, batteries and infrastructure—the reviewer found that the project seems likely to have a lesser impact, as the factors that dictate these costs are beyond the scope of what the project can substantively influence. The reviewer noted that the presentation gave a small mention of future commercialization research, but recommended that this be a stronger point of emphasis in the final year of the project, to more rigorously quantify realistic pathways for the technologies to achieve broad commercialization. The reviewer commented on how far those pathways are from present day conditions.

Reviewer 4:

The reviewer observed that the strategic plan for future research and testing, in particular, was not included in the presentation. The reviewer expressed hope that with the different varieties of fuel cell technologies, the future test plan would take advantage of seeing what type of deployment—application and duty cycle—would best fit the battery-dominant trucks—BAE/CTI, Transpower, and Hydrogenics—and the fuel-cell dominant trucks—US Hybrid. The reviewer stated that it is not clear that this would be an apples-to-apples comparison, because the power, torque, range, and other performance specifications may not be the same across all four trucks, and the presentation did not contain one chart showing or comparing all of these features at the same time.

Reviewer 5:

The reviewer found this to be the weakest portion of the presentation. The reviewer observed that a number of interesting and varying technologies will be deployed to address zero-emission requirements; however, there was no clear formulation of how or what data would be collected from the vehicles and how it would be used to best understand the technologies and benefits. The reviewer expressed the view that this work would be improved by a more concerted effort in developing the data acquisition and analysis side once all of the vehicles go into use, and stated that this would be a critical step in relaying information to industry and program partners about the performance of the technologies investigated.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer commented that this project is relevant because it meets the DOE objective of petroleum displacement, and as hydrogen is a clean fuel producing no emissions, it serves national environmental goals as well. The reviewer stated that this research and testing could not, and would not, have been done by the private sector.

Reviewer 2:
In the reviewer's opinion, this project lines up directly with DOE's objective to reduce our dependence on petroleum, and it also reduces local air pollution, which is the key objective of the participants.

Reviewer 3:
The reviewer found the project to be relevant for objectives of diversifying cargo transport fuel sources and addressing adverse emissions conditions at ports, and thought that the presentation stated that 16,000 drayage trucks currently service the San Pedro Ports.

Reviewer 4:
The reviewer stated that each of the technologies under investigation demonstrates reduced petroleum consumption, across a broad spectrum of approaches.

Reviewer 5:
The reviewer expressed the view that, for zero-emission trucks to take off, it will take deployment projects like this to advance them with any speed.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that this project has a large budget, but the participants are doing a lot, including custom-building a set of trucks, using rather costly new technologies, so they will need all the money they have. The reviewer expressed hope that the trucks will operate well, so that they will actually be more efficient to operate than those they are replacing.

Reviewer 2:
The reviewer stated that the project has a sizeable budget, but is also relatively ambitious for producing seven vehicles with five different powertrain configurations, to explore the potential of zero- or near-zero-emission technologies for port drayage operation.

Reviewer 3:
The reviewer observed that any project involving hydrogen fuel cells is going to be rather expensive, and any project involving retrofitting trucks requires custom tailored engineering and labor-intensive effort. The reviewer expects this project to be expensive.

Reviewer 4:
The reviewer stated that this is a well-funded project.

Reviewer 5:
The reviewer stated that the program is ending soon, and resources are sufficient.

Presentation Number: elt187
Presentation Title: Comprehensive Assessment of On- and Off-Board, Vehicle-to-Grid Technology Performance and Impacts on Batteries and the Grid
Principal Investigator: Sunil Chhaya (EPRI)

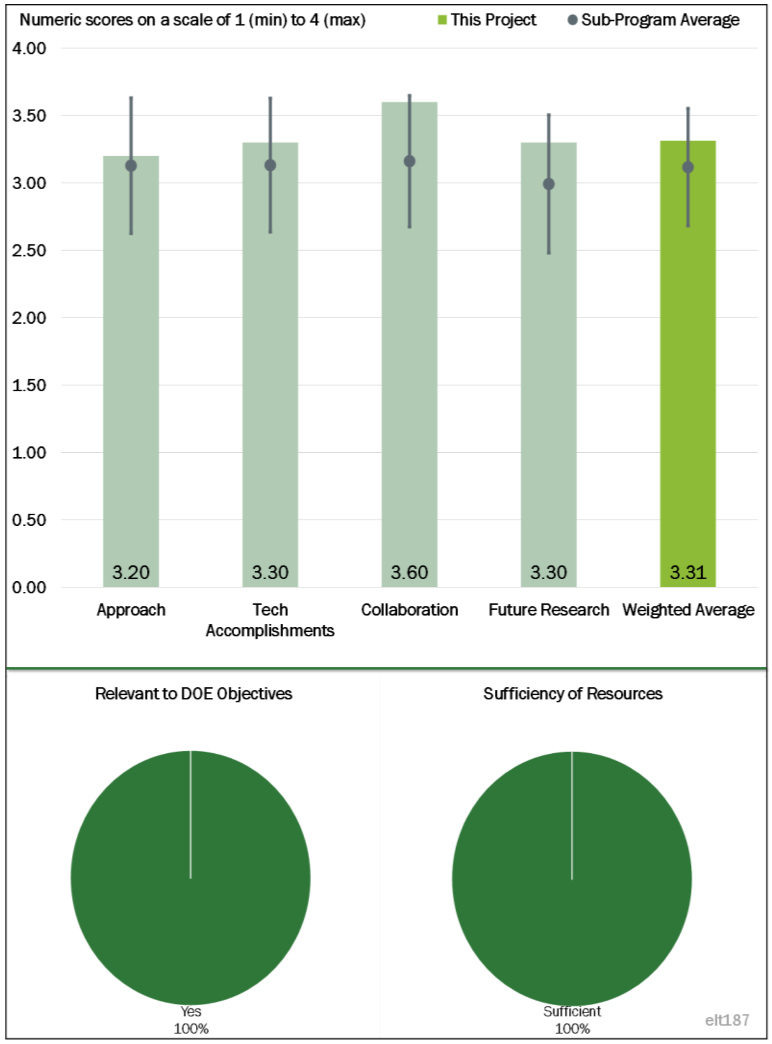

Figure 4-21 -Presentation Number: elt187 Presentation Title: Comprehensive Assessment of On- and Off-Board, Vehicle-to-Grid Technology Performance and Impacts on Batteries and the Grid Principal Investigator: Sunil Chhaya (EPRI

Presenter
Sunil Chhaya, EPRI

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer stated that the project objectives are a good step to understand the impact of vehicle to grid (V2G) services on the vehicle.

Reviewer 2:
The reviewer noted that the approach is two-fold in design, focusing on both on-vehicle AC V2G, and off-vehicle DC V2G, and that both are important to understand, to address the full picture. The reviewer commented that the key enabler for this project is the Smart Power Integrated Node for integrating V2G, as well as renewable resources and stationary energy storage, all into a local controlled system. The reviewer further commented that this project also specifically targets the industry Society of Automotive Engineers (SAE) standards, which are key to successful implementation.

Reviewer 3:
The reviewer stated that the project is coming along well and barriers appear to be addressed.

Reviewer 4:
The reviewer commented that the proposed control method appears to be a good solution to optimizing power flow among distributed energy sources and plug-in electric vehicles (PEVs).

Reviewer 5:
The reviewer commented that the approach does not consider all available open standard architectures, such as ISO 15118, which is already a reference standard for J1772 CCS DC charging.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the project has developed the capability to monitor and control transformers, which is significant for impacting local electricity supply. The reviewer noted that the project is currently operating four vehicles in the field as part of the demonstration and verification of this capability, and that multiple cost savings scenarios were developed, including baseline, with solar, and optimized with solar.

Reviewer 2:

The reviewer observed that the test vehicles are completed and deployed for testing, and the remaining activities are on track.

Reviewer 3:

The reviewer observed that almost all tasks are complete now, moving into the testing stage, and the test plan is completed. The reviewer further noted that on-vehicle V2G technology has been integrated and demonstrated on four vehicles.

Reviewer 4:

In the reviewer's view, the team appears to be making good progress on software development and the hardware demonstration.

Reviewer 5:

The reviewer noted that progress towards the battery durability impact study is not identified.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the project is well-coordinated among the team.

Reviewer 2:

The reviewer observed that separate organizations cover different aspects of the project, and the completion of various deliverables indicates the team is collaborating well and closely.

Reviewer 3:

The reviewer stated that the team includes a broad range of participants directly or for coordination, including the Electric Power Research Institute (EPRI)—the project lead—national laboratories, an OEM, a battery manufacturer, and control and systems firms, and that these appear to be exactly the parties necessary to make progress in this area.

Reviewer 4:

The reviewer stated that the project is on time and coordination with partners is not an issue.

Reviewer 5:

The reviewer stated that the team is working with several organizations to ensure the project is successful.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

In the reviewer's estimation, the team appears to have a good plan in place.

Reviewer 2:
The reviewer noted that no proposed future research is called out, and the evaluation is based on the remaining tasks listed for Budget Period 2. The reviewer found the tasks to be appropriate to answer the questions posed for the project.

Reviewer 3:
The reviewer stated that the project team has identified a detailed list of important remaining challenges and barriers. The reviewer added that, at this time, it is unclear how many can be addressed under this project, but it is a useful list to have.

Reviewer 4:
The reviewer observed that concerns over potential battery life were discussed, although the charging duty cycles appear to be low impact relative to vehicle level requirements. The reviewer further observed that the emphasis on addressing the V2G open standards was also highlighted and is critical. The reviewer noted that the project team is aware of the issues to overcome for the remainder of the project, and the issues to address ahead.

Reviewer 5:
The reviewer commented that Underwriters Laboratories (UL) qualification, or gap analysis, is essential for determining the industrialization path.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented that the project enhances desirable characteristics and diminishes vulnerabilities of the U.S. energy infrastructure, while meeting environmental responsibilities.

Reviewer 2:
The reviewer noted that this project is focused on gaining a better understanding of key elements of integration between PEVs and the grid, to not only project costs and energy impacts, but also to improve control. The reviewer added that this will also assist in allowing greater integration of renewable energy sources. The reviewer commented that, as part of the overall effort, this project is working to address the specific lack of data on distributed energy resources, while looking at both on- and off-vehicle hardware, as well as standards verification. The reviewer added that all of these areas need to a better understanding to provide for a successful transition to greater effective deployment of EV technologies, a key objective for DOE.

Reviewer 3:
In the reviewer’s estimation, this project has the potential to reduce peak power requirements and energy costs, while meeting the needs of PEV owners.

Reviewer 4:
The reviewer found that the project supports DOE investigation of PEV technologies and their impact on the electric grid.

Reviewer 5:
The reviewer stated that, for future connected, or V2G, vehicles to have an impact on energy consumption reduction, a number of technical approaches to the connectivity and interoperability need to be investigated and well understood. The reviewer found that this project addresses some of the hurdles in examining the potential impact such technologies could have in the future.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed that resources appear sufficient at this time; however, depending on how many of the remaining challenges and barriers are accomplished under this project, there may be a future need for additional funding to address the remaining ones.

Reviewer 2:
The reviewer noted that there were well-established collaborators and resources.

Reviewer 3:
The reviewer stated that resources are sufficient for the project and good progress is being made.

Reviewer 4:
The reviewer stated that the project is on track with the given resources.

Reviewer 5:
The reviewer stated that the resources appear to be sufficient.

Presentation Number: elt188
Presentation Title: Bi-Directional Wireless Power Flow for Medium-Duty Vehicle-to-Grid Connectivity
Principal Investigator: Steven Sokolsky (CALSTART)

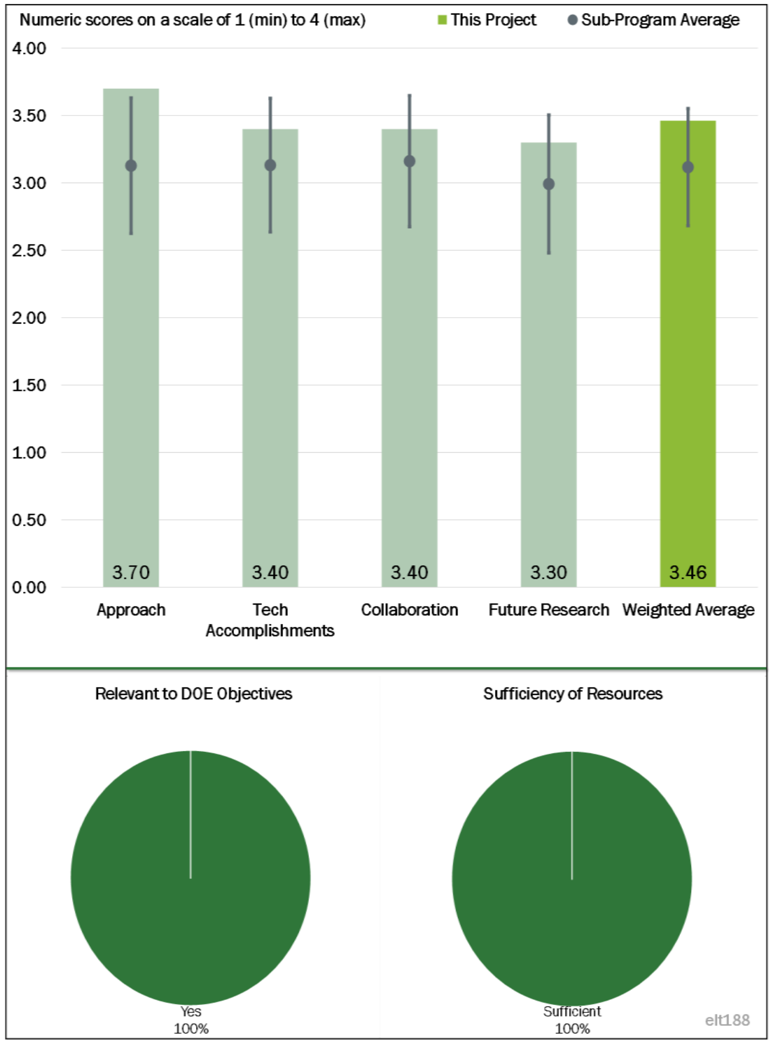

Figure 4-22 - Presentation Number: elt188 Presentation Title: Bi-Directional Wireless Power Flow for Medium-Duty Vehicle-to-Grid Connectivity Principal Investigator: Steven Sokolsky (CALSTART)

Presenter

Steven Sokolsky, CALSTART

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed that the project team has the right approach for reaching the objective of developing a test prototype of a bi-directional wireless power transfer (WPT) system with large air gap between primary and secondary.

Reviewer 2:

The reviewer stated that the project had a well-defined strategy.

Reviewer 3:

The reviewer noted that this project started with evaluating a real-world application and proceeded to design a system that could prove the proof of concept for bi-directional wireless charging on MD trucks. The reviewer commented including a partner that would provide the true operational parameters provides realism to the design constraints and enhances the proof of concept. The reviewer noted that the project also explores how to do wireless with an 11” gap, 20 kW to the truck and 6.6 kW V2G.

Reviewer 4:

The reviewer commented that, on the surface, this project does address many barriers with wireless conductivity (bi-directional), but most of the issues can be captured in the large air gap assessment and efficiencies. The reviewer added that the work and design appear to be very solid in engineering detail; however, great physical assessment will be necessary to confirm the efficiencies calculated.

Reviewer 5:

The reviewer commented that the basic technical questions are all covered. Not knowing anything, the reviewer questioned the robustness of the system for vibration, and the possibility of radiation leakage caused by the large air gap.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed that the team has achieved its first-year milestone and appears to be on track for year 2 milestone. The reviewer added that the team presented ample proof that the simulated system design meets the requirements.

Reviewer 2:

The reviewer commented that this is a proof of concept design project which will deliver a prototype system, and that the project uses the constraints and operational parameters of the partner organization. The reviewer noted that the project is following typical engineering practices and has used simulation in the design requirements phase. The reviewer added that coupling coils are designed, the models of control systems are complete, and it was modeled across operating parameter ranges, i.e., gap. 93% efficiency predicted through simulations. The reviewer commented that these are all good technical accomplishments in the first period.

Reviewer 3:

The reviewer remarked that if the efficiencies can be confirmed in demonstration, this review will be elevated to outstanding.

Reviewer 4:

The reviewer commented that interoperability testing of primary and secondary sides can be at risk if primary and secondary sides are designed and tested independently, as presented. The reviewer added that parallel design, assembly and testing of primary and secondary sides should be considered.

Reviewer 5:

The reviewer remarked that it is difficult for a non-specialist to provide an informed review of the progress, because the presentation provided detailed charts without explanation of definition of variables. The reviewer added that it was hard to know how much of what was done was novel, and how much was standard. The reviewer recommended showing a state-of-the-art system and adding novel features in bright color so it is possible to review without expert knowledge, as well as telling the reviewers what is new and different, and why it was hard or interesting.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that there were well-established, strong partners

Reviewer 2:

The reviewer remarked that the level of success is proportional to the depth of successful collaboration, and UPS and Workhorse are very motivated for energy savings in their operations.

Reviewer 3:

The reviewer commented that, for the intended objectives of the project, the collaborations are extremely good; however, to make it even stronger, the project needs an advisory partner who would cost and build the system in volume.

Reviewer 4:

The reviewer indicated that the project results are strong and the development appears to be well-coordinated. The reviewer noted that one possible improvement would be to show when specific project partners are engaged on the work plan; for example, the work plan should show symbols for design reviews that include the integration partners.

Reviewer 5:
The reviewer remarked that, so far, there is no evidence of collaboration. The reviewer added that it looks like ORNL has been modeling and designing energetically, but there is no evidence of inputs from the eventual customer. The reviewer assumed that some constraints on size, etc. were provided by partners and built into the design.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer observed that the project had an appropriate go/no-go decision point at the completion of the simulation design phase and has an appropriate deliverable scheduled at the end of the bench testing phase.

Reviewer 2:
The reviewer commented that demonstration delivery by 2019 is aggressive with hardware, but tracking indicators appear on time.

Reviewer 3:
The reviewer stated that communication requirements and impact on the grid (loss of packages, speed of communication, etc.) are critical parameters to have evaluated.

Reviewer 4:
The reviewer noted that the process being employed outlined the work to be performed in subsequent phases. The reviewer added that the process is following a development method, but because no build partner or commercial collaborator is identified, the true challenge of knowing the ROI on such a system will not be explored.

Reviewer 5:
The reviewer remarked that future work is only described in broad generality. The reviewer recommended including an analysis of what the operating scenarios might be, such as what power is stored, where and when, what is it used for, etc., in future work.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer remarked that the project certainly supports DOE objectives, and added that technologies such as bi-directional electric storage and power transfer are essential to demonstration of the efficiency that electrification may bring to society.

Reviewer 2:
The reviewer observed that the project supports DOE's overall objectives for advancing MD and HD EV charging capabilities. The reviewer added that this technology advances the state-of-the-art for wireless charging of MD and HD vehicles, especially in its bi-directional power transfer feature. The reviewer commented that it is important that DOE has an accurate characterization of bi-directional WPT to accurately assess the potential interactions of EVs with local microgrids, and possible interactions with—and impacts on—the performance and stability of the electric grid distribution network.

Reviewer 3:
The reviewer commented that the project supports electrification, which in turn supports petroleum reduction.

Reviewer 4:

The reviewer noted that the project focuses on infrastructure challenges, and will identify the opportunities for grid stability.

Reviewer 5:

The reviewer commented that the primary objectives do support the DOE objectives, as the project would enable the use of more fuel-efficient systems, namely electricity, for MD trucks. The reviewer added that the main question is what the strategy would be for when the vehicle batteries provide power to the grid, or are used in the sorting and loading facility to mitigate demand charges, and questioned what the gain is when the power goes back, and who uses it to obtain that cost advantage.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the budget should be sufficient for design and build.

Reviewer 2:

The reviewer observed that the project has a very competent group with a proven track record to design, test and deploy a prototype system.

Reviewer 3:

The reviewer noted that the project has well established collaborators and resources

Reviewer 4:

The reviewer commented that, lacking any discussion to the contrary, the funding levels appear to be appropriate to the objectives described in the program.

Reviewer 5:

The reviewer noted that the resources have been adequate during the first phase, and the presenter gave no indication that the project had any concerns regarding resources.

Presentation Number: elt189
Presentation Title: Electric Truck with Range-Extending Engine (ETREE)
Principal Investigator: John Kresse (Cummins)

Presenter
John Kresse, Cummins

Reviewer Sample Size
A total of five reviewers evaluated this project.

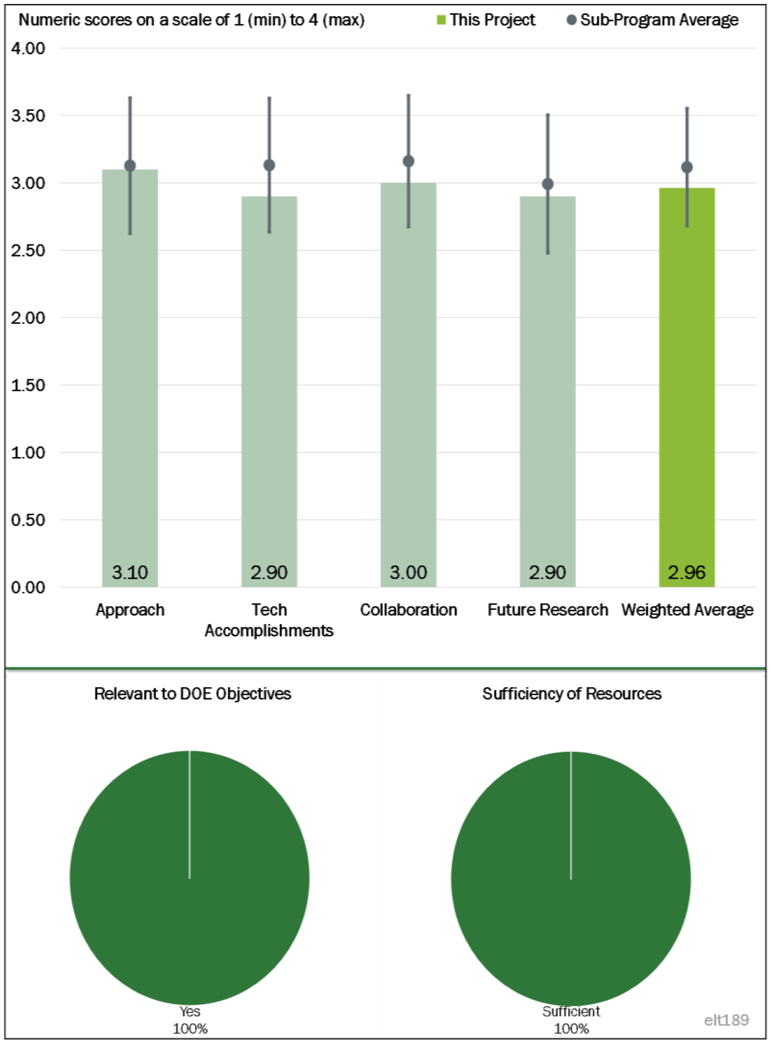

Figure 4-23 - Presentation Number: elt189 Presentation Title: Electric Truck with Range-Extending Engine (ETREE) Principal Investigator: John Kresse (Cummins)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer stated that this is a strong approach to this battery dominant hybrid truck development. The reviewer noted that there is a great deal of work going on with fully battery electric trucks and with their simplicity, rightly so, and added that hybrids by their nature take a rather complex powertrain of a diesel engine and its aftertreatment and add more complexity with the battery systems. In the reviewer's opinion, with range concerns, it will be very possible that hybrids will remain a solution. The reviewer commented that Cummins is doing a great job with this project.

Reviewer 2:
The reviewer observed that the project team focused heavily during the initial phase on development of key requirements, and commented that this was a good approach to minimize risk in later phases.

Reviewer 3:
The reviewer remarked that the approach seems to be on the right track; however, issues with the battery might delay the timing, making it too critical to achieve the validation demonstration phase.

Reviewer 4:
The reviewer commented that it is a $6 million program, and its relevance is related to risks associated with the real-world achievement of the fuel economy gains being sought. The reviewer noted that the approach does have a few things that may create limitations when the vehicle system is produced. First, a series of real-world routes would have been more appropriate to use as design criteria where the worst cases of the consolidated set of routes were used as design criteria. Second, it seems that because the engine choices were limited, it may have constrained the thinking regarding how to achieve the performance. The reviewer commented that other projects are using much smaller engines and have shown in similar types of simulations that they can achieve

the fuel economy objectives at much lower total system weight. The reviewer added that this is a low-risk approach when looking at meeting legacy customer expectations, which may need to change a bit if more significant gains are to be achieved.

Reviewer 5:

In the reviewer's opinion, this project is not an applicable solution for the current fast-changing environment because it is overly complicated and oversized, and noted that by the time it could become any kind of marketable solution, it will be outdated.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that having to change battery suppliers is not good, but with so much development going on with batteries, it is not surprising, and this will likely happen to a small, but not inconsequential degree with production HEVs and battery-electric vehicles (BEVs). The reviewer commented that the team is managing this well and achieving program success with minimal delays.

Reviewer 2:

The reviewer commented that the project team needs to overcome the battery concerns, and added that the project did not address the potential performance concerns under cold weather conditions.

Reviewer 3:

The reviewer observed that significant loss of time occurred because of major shifts in major component subsystems, and restrictions on charging power for vehicles that have very large batteries is a business risk. In the reviewer's opinion, these decisions seem to be based on legacy thought processes where organizations just want nothing to change and all of the gains to be still available; however, this is not a plausible outcome very often, and it leads to putting artificial barriers in the road to progress. The reviewer commented that change can be designed that will result in a better system that may require just a bit of change, such as some small adaptation to accommodate diesel filter re-generation that can be programmed in. As examples, the reviewer noted a 4 month delay due to battery change, a targeted November 1, 2018 delivery to Frito Lay, Frito Lay's desire for low-level charging at low cost and the need for the range extender to reposition trucks in the fleet. The reviewer commented on good specification development, including 10 minute grade capability, 270 mile combined range, targeted 80 daily miles for the range extender to meet a high percentage of usage cycles, a 112 kWh lithium-ion 700 volt battery, 130 kW generator and 165 kW motor. The reviewer noted a 64.6 % fuel reduction in hardware-in-the-loop (HIL) test on the NREL 80-mile duty cycle test. NREL added 3400 lbs.

Reviewer 4:

The reviewer commented that the payback chart was unclear. The reviewer also noted that the presentation stated that battery failures were an issue and that thermal management was not needed on the batteries.

Reviewer 5:

The reviewer noted that the technical accomplishments are on track to the team's plan, and that the system is viable for the demonstration purposes, but seems to require significant modifications and upgrades to both hardware and software, to be commercially viable.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer observed that coordination on the project between team members appears to be good.

Reviewer 2:
The reviewer commented that the project has solid partners, and expressed interest in knowing what PepsiCo specifically thinks of the potential of this design, as they and other fleets will be the determining factor.

Reviewer 3:
The reviewer noted evidence of meeting technical goals and limiting timeline delays.

Reviewer 4:
The reviewer noted a full and complete group of collaborators, but there is an element of having some of them provide pre-conceived constraints to the development process. In the reviewer's opinion, it would have been better if the partners had been a bit more flexible, to actually test the new characteristics and then re-calibrate them out if there was a problem with operation in the real-world testing.

Reviewer 5:
The reviewer stated that payback viability was not demonstrated.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the test plan and development change of the battery system show a good understanding of the need to build a robust system. The reviewer expects that the system as designed will be quite good in the test program.

Reviewer 2:
The reviewer commented on the strong plan moving forward.

Reviewer 3:
The reviewer noted that vehicle build and fleet testing are future plans for this project, and it will be important to create a robust data acquisition and analysis plan.

Reviewer 4:
The reviewer commented that battery payback, and timing to deliver vehicles and start the demonstration validation, are areas of concern that need to be addressed.

Reviewer 5:
The reviewer commented that the partners have the potential to develop solutions, but it would be a more cost-effective use of DOE funds to re-evaluate the outdated areas of the design. In the reviewer's opinion, streamlining or eliminating specific components may be a more realistic marketable approach.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer found that this project meets overall DOE energy and fuel savings objectives.

Reviewer 2:
The reviewer commented that the project is relevant to the need for energy efficiency in transportation.

Reviewer 3:
The reviewer stated that electrified technology and commercializing it in large class vehicles are critical, and noted the need to monitor the execution carefully to assure staying on track.

Reviewer 4:
The reviewer commented that this program will create higher energy efficiency than the base system, and that if it does meet ROI objectives, it will be successful.

Reviewer 5:
The reviewer commented that this project definitely supports overall DOE objectives, but noted real range issues, and not just range anxiety. The reviewer stated that a diesel truck can run a week on one fuel-up, but BEVs will only be designed for a day’s run.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer found that resources are sufficient.

Reviewer 2:
The reviewer commented that resources appear adequate to meet overall project goals and tasks.

Reviewer 3:
The reviewer noted that the project seems to have sufficient resources, based on what was presented.

Reviewer 4:
The reviewer stated that these partners have all of the needed resources; they just have to apply them to the program.

Presentation Number: elt190
Presentation Title: Medium-Duty Urban Range Extended Connected Powertrain (MURECP)
Principal Investigator: Alexander Freitag (Bosch)

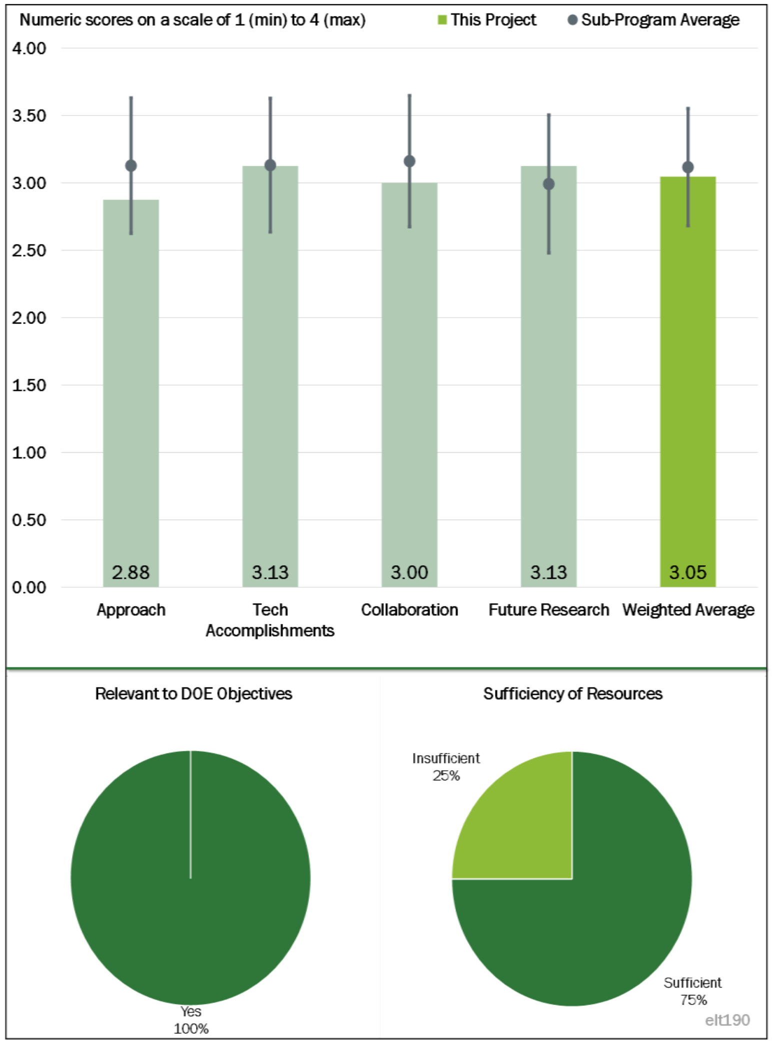

Figure 4-24 - Presentation Number: elt190 Presentation Title: Medium-Duty Urban Range Extended Connected Powertrain (MURECP) Principal Investigator: Alexander Freitag (Bosch)

Presenter
Matt Thorington, Bosch

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer found the approach to be satisfactory, based on the timing outline and the key deliverables, but commented that the demonstration phase of only 6 months is too narrow to allow for real-world testing and evaluation.

Reviewer 2:
The reviewer commented that the project is highly focused on development of the Bosch portion of the system, and noted that more involvement by other parts of the system may help to improve the overall efficiency for vehicle and end customer applications.

Reviewer 3:
The reviewer stated that the diesel range extender engine adds complications with aftertreatment.

Reviewer 4:
The reviewer commented that the approach is not described for the identified 6 months of development for predictive control.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer noted solid progress with good partner engagement.

Reviewer 2:
The reviewer found that the project technical tasks are on track for the agreed objectives.

Reviewer 3:
The reviewer commented that the assumed electric power rate and discharge power level are not included.

Reviewer 4:
The reviewer observed that there are many assumptions that are yet to be proven during the demonstration phase, and that the plan needs to be closely monitored to assure success.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer noted good collaboration across the project team, and found that Bosch brings great value and provides a very good base to the project.

Reviewer 2:
The reviewer noted that the project demonstrates a strong collaboration among the team members.

Reviewer 3:
The reviewer stated that it is not clear that the interaction between all the team members is occurring as effectively as possible, and questioned whether the other team members were partners or just suppliers.

Reviewer 4:
The reviewer commented that there are too many collaborators involved, and saw a need for Bosch to assure the activities and deliverables are closely monitored.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the prototype build of two units and 6 months of customer testing is excellent for an effective evaluation.

Reviewer 2:
The reviewer noted good future potential, but stated that revisiting and updating the components, as technology is rapidly changing, should be included in the scope.

Reviewer 3:
The reviewer observed that critical challenges remain to be overcome, and that packaging and battery testing are critical. The reviewer also commented that the demonstration phase is limited to 6 months, and stated that this is too narrow to allow real-world testing.

Reviewer 4:
The reviewer indicated that it is not clear who is doing each task in the future research steps, and that the commercialization plan development process is also not clear.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that the project is very relevant to energy efficiency in transportation solutions.

Reviewer 2:
The reviewer noted that the project can help achieve a cleaner and more secure energy future.

Reviewer 3:
The reviewer found the project to be in line with DOE’s green technology goals.

Reviewer 4:
The reviewer commented that the project is expected to reduce fuel and energy usage, which aligns with DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the resources are sufficient to meet overall objectives.

Reviewer 2:
The reviewer observed that a number of critical activities are yet to be done, and recommended having a better focus on timing and execution.

Presentation Number: elt191
Presentation Title: Medium-Duty Vehicle Powertrain Electrification and Demonstration
Principal Investigator: Wiley McCoy (McLaren)

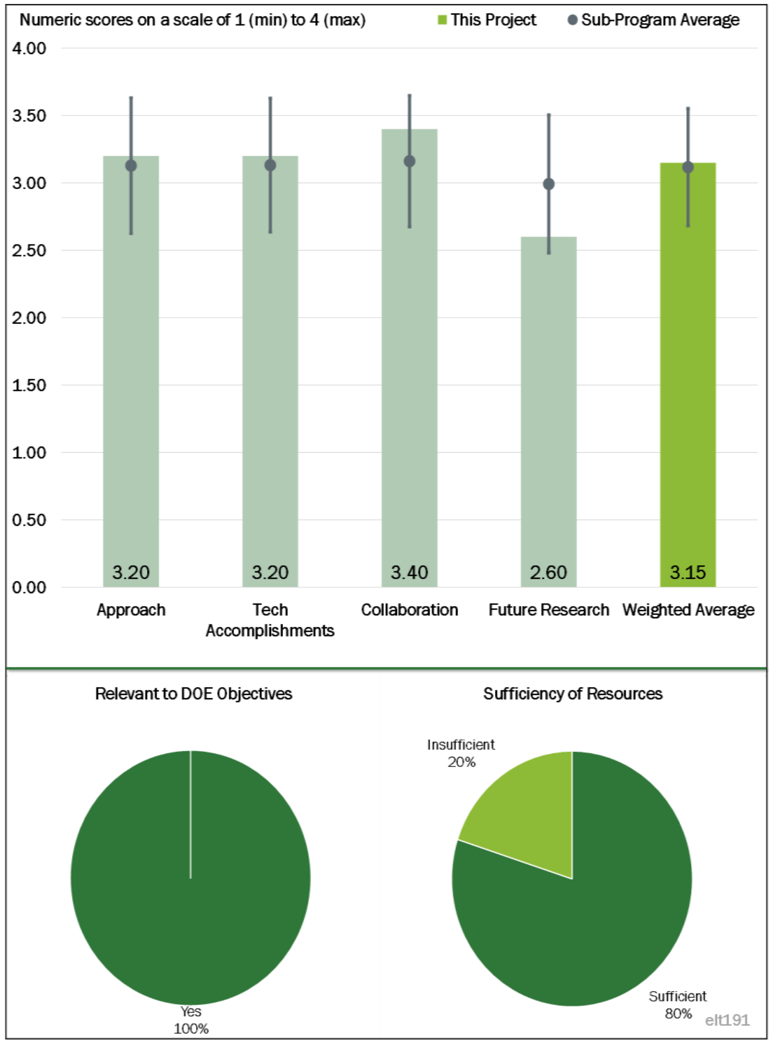

Figure 4-25 - Presentation Number: elt191 Presentation Title: Medium-Duty Vehicle Powertrain Electrification and Demonstration Principal Investigator: Wiley McCoy (McLaren)

Presenter

Wiley McCoy, McLaren

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the approach to doing the work is outstanding, because the primary objectives are to increase acceptance of the MD EVs and reduce costs associated with building a MD EV for the delivery market. The reviewer added that the work plan and progress reported reflect that the requirements for improved fuel efficiency and commercial viability are the focus of the work being performed.

Reviewer 2:

The reviewer stated that the approach is limited, but satisfactory to address the project's objectives.

Reviewer 3:

The reviewer commented that the approach is good, but there should have been more than the one objective defined for fuel efficiency; there should also be either reliability targets or vehicle performance targets, based on whatever the baseline vehicle is considered.

Reviewer 4:

The reviewer remarked that the project should look at a broader range of operations than those selected for Chula Vista, to ensure performance and results are representative across more of UPS' routes.

Reviewer 5:

The reviewer commented that the process used for selecting the electrification architecture is unclear, and that the authors should provide more details, to better assess whether the optimal solution was achieved, prior to the detailed design phase of the project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer found that the project seems to be on track to the committed schedule.

Reviewer 2:
According to the reviewer, it appears that the project team could have avoided a rework of the e-axle if they had been more rigorous in specifying component weight requirements. The reviewer found that the project team has created a design that meets their fuel efficiency improvement objective, and that the progress is taking a bit longer than initially scheduled, which is indicative that they are being true to their goal of producing a refined design that is capable of being commercialized. The reviewer added that the fact that the project team is taking the time to refine the design and incorporate feedback from the manufacturing team may be a good sign of the long-term impact of this project.

Reviewer 3:
The reviewer noted that some of the accomplishments are late, according to the original timeline, and commented that Slide 16 was a verbal update, but the contents should have been included in the presentation. The reviewer added that the metrics are all based on simulation data and HIL, and expressed an interest in seeing if the real-world testing will achieve the targets.

Reviewer 4:
The reviewer noted that the project team is trying to maintain the plan, in spite of challenges.

Reviewer 5:
In the reviewer's opinion, the project should better discuss the overall project objectives of a retrofittable design, or how easily it could be designed into other chassis; this was not discussed in enough detail.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer was impressed by the evidence of effective partner collaboration, based on the dropped alternative fuel requirement of the range extender. The reviewer noted that Ford wanted the requirement dropped, and the project team accommodated Ford's change request.

Reviewer 2:
The reviewer noted a very good list of partners which support project deliveries are collected.

Reviewer 3:
The reviewer noted good collaboration with the UPS team and chassis builder.

Reviewer 4:
The reviewer noted that the level of coordination between the team members seems to be good.

Reviewer 5:
The reviewer commented that the project information discussed was too focused on the PI's own business in general.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
According to the reviewer, it appears that the planned testing period will likely be shortened, due to slippage in the delivery schedule, and the reduced testing time may reduce some of the information value from the project, although it is not the end of the world; if the technology gets a commercial foothold, then reliability data will be developed later.

Reviewer 2:
The reviewer remarked that, because this system is expected to result in a commercialization demonstration, the team needs to give more consideration to other use cases, such as extreme environmental and operational schedules, to ensure that the design not only meets nominal program commitments, but also is capable of meeting all the marketplace demands.

Reviewer 3:
The reviewer commented that specific challenges were not identified, and future outreach was not outlined.

Reviewer 4:
The reviewer observed that future work was discussed with the test plan for four vehicles, but the commercialization plan and future for the technology build and deployment could be discussed in more detail.

Reviewer 5:
The reviewer commented that too many challenges lie ahead, with building the vehicles and starting the test; there are problems that need to be solved.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted excellent relevance to DOE's early technology level development goals.

Reviewer 2:
The reviewer commented that the project supports DOE's objective to advance the state-of-the-art for MD EVs. The project introduces an on-board range extender to the MD EV that allows the vehicle to maintain SOC and extend its operating range. The reviewer noted that the project advances MD EV components (e.g., e-axle, range-extender) that will enable practical commercialization of the technology to meet real-world delivery vehicle requirements.

Reviewer 3:
The reviewer stated that the project is aimed at energy usage reduction, and therefore it aligns with DOE objectives.

Reviewer 4:
The reviewer indicated that the project supports the DOE objectives of electrification and increased efficiency and fuel economy.

Reviewer 5:
The reviewer found the project and the technology itself to be in line with DOE's objectives; however, the project team needs to focus on the targets to measure success.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the project seems to be sufficiently funded to meet the project timing and deliverables.

Reviewer 2:
The reviewer stated that the resources seem sufficient.

Reviewer 3:
The reviewer noted that the project team is not requesting additional funding from DOE and the project will continue to completion; however, it appears that the project partners may have to make up for additional costs, as the budget numbers provided indicate that 13% of the funds are remaining, while 30% of the work remains to be done.

Reviewer 4:
The reviewer commented that there were too many challenges to overcome; the project needs more focus on timing, issues resolution, and demonstration testing.

Presentation Number: elt193
Presentation Title: Grid Modernization Laboratory Consortium: Vehicle-to-Grid Integration Pathway (GM0062)
Principal Investigator: Rick Pratt (Pacific Northwest National Laboratory)

Presenter

Rick Pratt, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

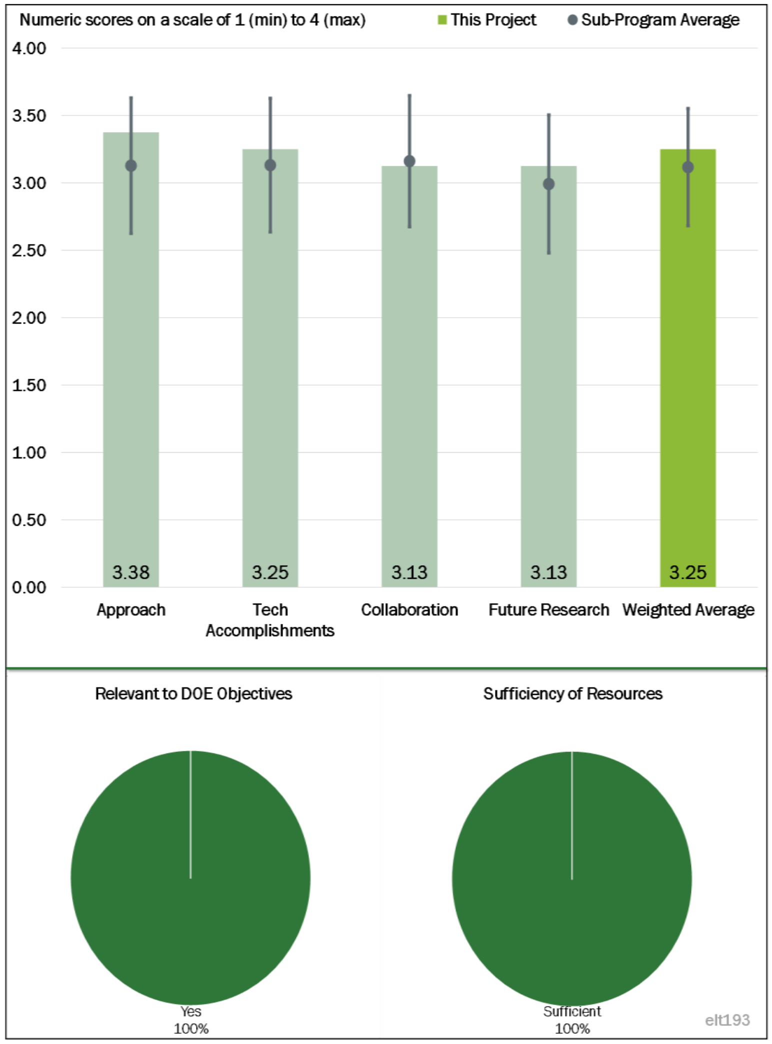

Figure 4-26 - Presentation Number: elt193 Presentation Title: Grid Modernization Laboratory Consortium: Vehicle-to-Grid Integration Pathway (GM0062) Principal Investigator: Rick Pratt (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that providing a demonstration of a V2G system that manages power consumption while meeting drivers' needs is an excellent method of promoting PEV adoption.

Reviewer 2:

The reviewer commented that because V2G integration involves infrastructure matters, the approach taken here with a broad range of national laboratories and industries is good. The reviewer found that the focus on use cases, demonstration, demand response, and demand mitigation is also quite agreeable.

Reviewer 3:

The reviewer observed that the national laboratories focus their efforts on areas of strength for each, and the overall project is well-conceived.

Reviewer 4:

The reviewer remarked that the approach goes deeply into certain aspects of the problem as presented in the use cases for these national laboratory buildings; however, it will not include enough variables on user requirements that may exist in a more varied-use building in the commercial world. For the environment being studied, the project has good use cases, the project team included the input of stakeholders, controlled versus uncontrolled charging implications and challenges, and the criteria for demand charges. The reviewer noted that a more commercial environment will have more varied-use cases—like visitors that arrive in EVs for 1 hour—that can create many new issues that these analyses may not cover.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found that the team is making good progress on the demonstrations and simulations of case studies.

Reviewer 2:

The reviewer found the charge demand response and mitigation demonstration to be good. The reviewer noted that the economic analysis numbers were relevant for certain specific assumptions, and recommended checking how the resulting numbers would be affected by different assumption sets (parameter sensitivity).

Reviewer 3:

The reviewer noted that the presenter spent time showing why users need to avoid demand charges due to costs; however, this was obvious and could have been briefer. Further, the economic analysis that showed savings included only averages and therefore was not really well done. The reviewer added that, in questioning, the presenter indicated there was much more behind the slide, but those things should have been shown. In addition, the various use profiles of the vehicles—different commute distances and SOC upon arrival—need to be statistically sampled and used to develop the solution logic for controlling charging and demand charges simultaneously.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the collaboration among a broad range of industries and national laboratories is very good.

Reviewer 2:

The reviewer commented that the team is communicating with several industry advisors to prioritize use cases, and the team is working with several other national laboratories to ensure successful demonstrations.

Reviewer 3:

The reviewer commented that the project team is all DOE internal collaborations, and questioned where the outside stakeholders are that affect this project, such as the utilities and commercial building control systems providers.

Reviewer 4:

The reviewer noted that, as presented, there does not appear to be a deep level of close and frequent coordination between the national laboratories, and suggested that the project could benefit from more frequent interaction between the teams.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer observed that the team appears to have a good plan in place.

Reviewer 2:

The reviewer stated that the plan for future research is good, and noted that having a plan to disseminate results and findings from the study to key players and get feedback on conclusions would be beneficial.

Reviewer 3:
The reviewer stated that the proposed future research items are good. The reviewer added that it might be a good idea to classify the numerous use cases and use scenarios to understand the various possibilities in a structured manner. The reviewer also noted that it looks like the study is assuming a normal operating situation, and, although the probability would be low, a V2G integrated system could play a significant role in a badly abnormal situation, such as a region-wide power outage or natural disasters. The reviewer is wondering if such abnormal scenarios are in the scope of this project.

Reviewer 4:
The reviewer commented that, with the shortcomings in the approach, the future work, as described, will not be applicable beyond the constrained use profiles being studied. The reviewer added that this project needs to expand itself beyond the DOE building scenarios being studied.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer noted that V2G integration is becoming a more and more important theme, as EVs gain deeper market penetration and as more charging infrastructure is constructed; renewable energy distributed power infrastructure and smart and/or zero-energy buildings are also linked. The reviewer commented that these background and ongoing changes make this study more and more relevant.

Reviewer 2:
The reviewer commented that energy demand on the grid side is important, and it is good to see DOE being proactive to potential failure modes for adoption of hybrid and EVs.

Reviewer 3:
The reviewer stated that this project has the potential to increase the PEV adoption rate.

Reviewer 4:
The reviewer indicated that, yes, the subject is relevant, but as configured this project will have narrow utility; there needs to be an expansion of the stakeholder base to understand more complicated use cases for vehicles and charging scenarios to create a wide-ranging use of the outcomes.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer indicated that resources appear to be sufficient to execute the objectives of this project.

Reviewer 2:
The reviewer found that the project appears to have sufficient resources.

Reviewer 3:
The reviewer commented that it looks like the resources are currently sufficient, considering the proposed future research.

Reviewer 4:
The reviewer stated that the resources are sufficient, but are bordering on being excessive for what the outcome may yield. The reviewer suggested that more be done with these resources by employing more stakeholders and use cases.

Presentation Number: elt194
Presentation Title: Grid Modernization Laboratory Consortium: Systems Research for Standards and Interoperability (GM0085)
Principal Investigator: Don Scoffield (Idaho National Laboratory)

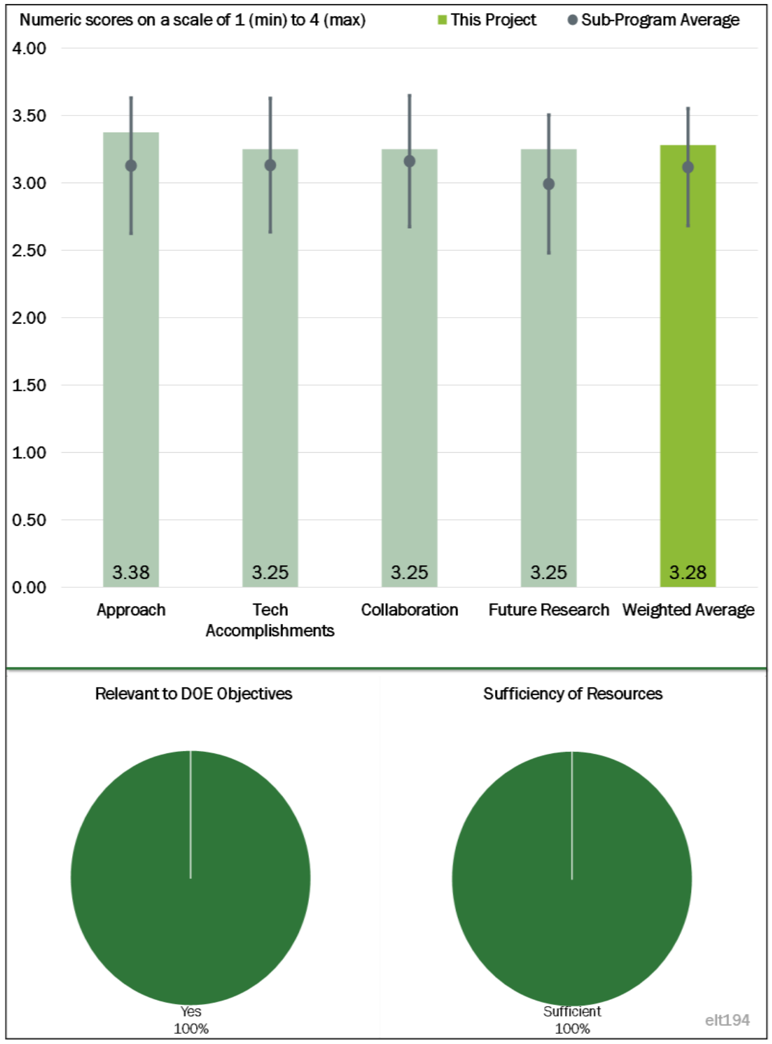

Figure 4-27 - Presentation Number: elt194 Presentation Title: Grid Modernization Laboratory Consortium: Systems Research for Standards and Interoperability (GM0085) Principal Investigator: Don Scoffield (Idaho National Laboratory)

Presenter

Don Scoffield, Idaho National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the "aggregator concept in the approach allows the team to get a handle on what is a somewhat open-ended question defined as a barrier.

Reviewer 2:

The reviewer commented that this approach will allow reduced peak power demand by controlling the rate of charging PEVs.

Reviewer 3:

The reviewer observed that the project intends to develop an aggregator platform that understands how charging can be controlled at the commercial building and/or the residence level. For commercial buildings, the aggregator control is within the building level. The residence real-time digital simulators (RTDs) connect the activity of all agent vehicles, and the aggregator is controlling charging thru RTDs with no building controller in between, as in commercial buildings.

The reviewer remarked that the research is an attempt to create a tool to solve the problem of how uncontrolled charging can affect power demand and cost, and therefore affect the adoption of zero-emission vehicles. The reviewer found this to be a good approach to try to find a solution to this issue.

Reviewer 4:

The reviewer noted that the slide titled "Approach: Quantify Benefit of Controlling PEV Charging" lists the following bullet: "After the simulations have been run, the economic benefits of controlling PEV charging will be quantified." In the reviewer's opinion, this bullet is not accurate in that it overstates the degree of economic analysis that the project has performed by an order of magnitude. The reviewer added that this project addresses a limited economic analysis that is confined to the distribution feeder expansion costs associated with aggregator-controlled charging.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer observed that progress has been excellent, with some interesting results showing the benefit of the aggregator concept.

Reviewer 2:
The reviewer stated that the project has made effective progress in that it has performed simulations and come to specific preliminary conclusions regarding potential benefits of aggregator controlled PEV charging. The reviewer added that the project has produced a clear story that deserves further refinement and validation.

Reviewer 3:
The reviewer found that the team has made good progress on modeling of the system and evaluating case studies.

Reviewer 4:
The reviewer noted that, so far, the progress has been to characterize PHEV in three use cases, to understand vehicle reactions that affect the grid. The reviewer observed that the first version of the aggregator communicates with EVs directly, and stated that this is reasonable progress for the time expended, and that the communication needs to be expanded to the building control units, where applicable, and to the utility.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer observed that an appropriate group of partners has been assembled, and the advisory board of utilities is an excellent adjunct source of feedback on the work.

Reviewer 2:
The reviewer stated that it is clear that the partners have collaborated to establish the use cases and development of the scenarios for the initial simulations, and noted that the schedule indicates the collaboration between the partners is going to increase significantly to accomplish the next phase of development.

Reviewer 3:
The reviewer found that the team is coordinating several organizations to ensure the project is successful.

Reviewer 4:
The reviewer commented that the collaborations are narrow and mostly laboratory-based, and added that significant and active input from the utility is needed for the successful development of the capabilities within the aggregator.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the next steps are logical follow-ups to the work already carried out.

Reviewer 2:
The reviewer found that the team has a good plan in place.

Reviewer 3:
The reviewer stated that the future research needs to have the aggregator be integrated or interconnected with the utility operation that supplies the building units, and possibly the building control systems.

Reviewer 4:
During the presentation, there was a statement that led the reviewer to believe that each of the national laboratories are doing their own, but similar, work in parallel, and that this may result in some duplication of effort. The reviewer suggested that it would be useful if the project could incorporate consideration of non-PEV building loads and building transformer cooling requirements into its scheduling of PEV charging.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented that the project supports DOE's investigation of the impact of PEVs on the electric grid. The reviewer added that the results help to answer critical questions about how well the existing grid infrastructure can support increased charge demand from PEVs and possible solutions to mitigate the impact of that demand.

Reviewer 2:
The reviewer stated that the project is relevant because it is an attempt to solve an issue that may impede the adoption of high-volume EVs.

Reviewer 3:
The reviewer noted that this project is exploring the feasibility and benefits of coordinated "central" control of PEV populations by a third-party aggregator. The reviewer commented that developing business cases related to PEV charging control strategies support DOE's objective to develop EV technologies that minimize the impacts of EV charging on the stability and reliability of the electric grid.

Reviewer 4:
The reviewer remarked that this project has the potential to reduce peak power requirements while meeting the needs of PEV users.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that the project is on track with the available resources.

Reviewer 2:
The reviewer commented that the project is funded with sufficient resources.

Reviewer 3:
The reviewer commented that the resources appear to be sufficient.

Reviewer 4:
The reviewer observed that the resources appear to be burning at a rate slightly faster than the schedule would warrant. The reviewer added the presentation indicates that 40% of the work remains, but it appears that the team has approximately one-third of the total project funds remaining; however, based on the work descriptions, the partners should be able to fit the remaining work to the available funds.

Presentation Number: elt196
Presentation Title: Grid Modernization Laboratory Consortium: Diagnostic Security Modules for Electric Vehicle-to-Building Integration (163)
Principal Investigator: Kenneth Rohde (Idaho National Laboratory)

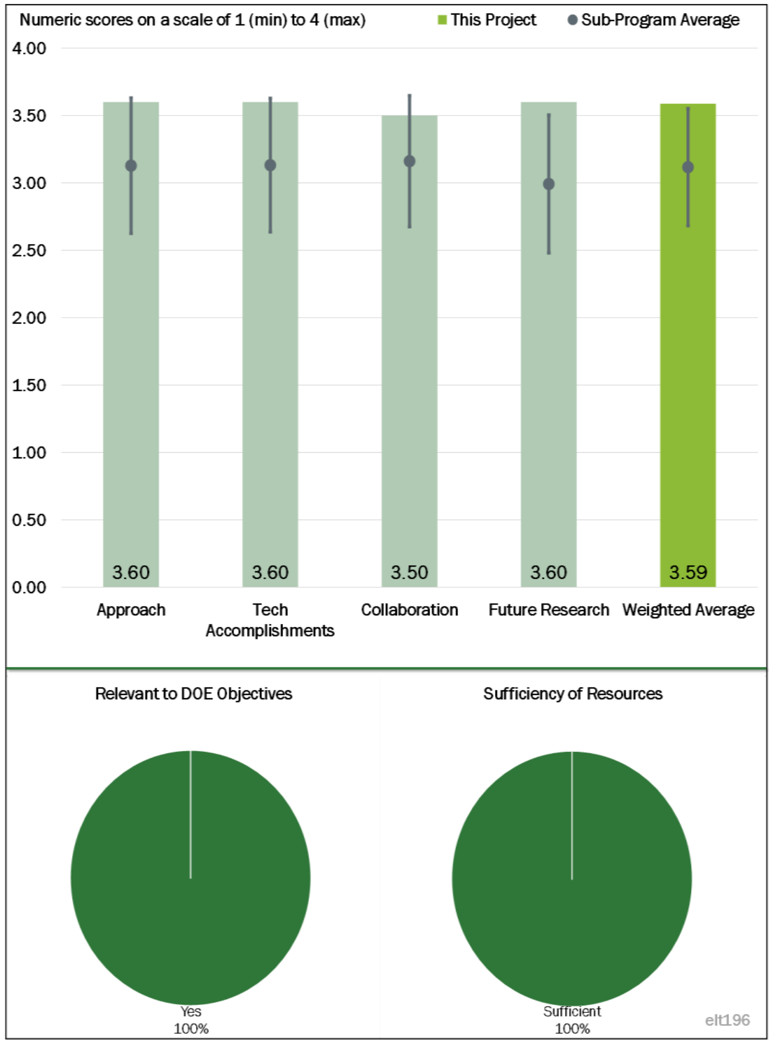

Figure 4-28 - Presentation Number: elt196 Presentation Title: Grid Modernization Laboratory Consortium: Diagnostic Security Modules for Electric Vehicle-to-Building Integration (163) Principal Investigator: Kenneth Rohde (Idaho National Laboratory)

Presenter
Kenneth Rohde, Idaho National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer declared this an excellent approach to using available resources to develop hardware that demonstrates the cybersecurity system principles in PEV charging applications.

Reviewer 2:
The reviewer stated that this is a very good approach to a very important issue that needs to be resolved before we can use a charging system safely for EVs.

Reviewer 3:
The reviewer stated that, fundamentally, programs to develop or evaluate vehicle-to-infrastructure (V2i) charging security are addressing an open issue, or gap, in the EV space that this project directly is addressing. The reviewer added that Idaho National Laboratory appears to be extremely qualified in its assessment of the technology and approach to the problem.

Reviewer 4:
The reviewer commented that this is an area in need of research, and this project fulfills a glaring need to secure the vehicle communication systems from cyberattack, and more importantly from transferring an attack to a building unit or to the grid. The reviewer added that the approach is to apply advanced cyber methods to these systems, knowing that there could be multiple system variations that need to be accommodated.

Reviewer 5:
The reviewer found this project to be a good approach to a critical area of charging and addressing key technical issues.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commended the project team for great work, and progress that is right on track.

Reviewer 2:

The reviewer commented on the large strides made in defining and implementing the system, starting from scratch.

Reviewer 3:

The reviewer stated that the project appears to be well-focused, and it demonstrated logical progression towards success. The reviewer added that deployment and demonstration of the diagnostic security module (DSM) will be critical in the project path, and it appears that this is being completed soon to overcome issues early enough to not jeopardize the project with delays.

Reviewer 4:

The reviewer commented that the project technical tasks are on target for meeting project timing and objectives.

Reviewer 5:

The reviewer commented that the project team has developed a framework to monitor the security state of the systems and provide information on risks to the building system. The reviewer noted that this project is not intended to produce a system to be sold and marketed, but to give system functionality guidance to stakeholders, and create knowledge for future system deployment. The team intends to demonstrate the project at CyberAuto 2019. The reviewer added that the team is working with the electric vehicle supply equipment (EVSE) provider, ChargePoint, using early specification EVs to understand how communications with the building need to be secured.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commended the project for its great collaboration and team members.

Reviewer 2:

The reviewer commented that ChargePoint is a very good collaborator to have in this space, and noted good use of the other team members to complete various parts of the project.

Reviewer 3:

The reviewer stated that most critical is the ChargePoint coordination, which will lead to hardware delivery, and added that the project has great credibility, with involvement from other national laboratories and some academia.

Reviewer 4:

The reviewer noted that collaboration does not seem highly coordinated, but it is sufficient to progress the overall objectives of the project at this stage; however, the reviewer would expect closer coordination and alignment for future efforts.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented that the project team has laid out a very straightforward plan for program completion to the proof of concept level that was described in the presentation.

Reviewer 2:
The reviewer stated that future plans are very relevant.

Reviewer 3:
The reviewer commented that the next steps are reasonable tasks for this project.

Reviewer 4:
The reviewer stated that the plan for future research is good.

Reviewer 5:
The reviewer noted that the project outline through 2019 appears to be technically aggressive without over-projecting, and expressed uncertainty about what, if any, post project research may be needed.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer stated that security of the applications of advanced technology is key to its success, and that if there are vulnerabilities identified in the field that jeopardize the building or grid, then strategic charging, one of the goals of electrification, cannot be achieved. The reviewer added that this project is proactive to this endeavor.

Reviewer 2:
The reviewer commented that securing the energy grid is a key aspect critical to the DOE mission, as electrification continues to penetrate the marketplace.

Reviewer 3:
The reviewer indicated that yes, this project is the kind of block and tackling necessary to make PEV deployment successful in the long run.

Reviewer 4:
The reviewer stated that the project supports energy efficiency because it supports the secure deployment of new systems in the marketplace.

Reviewer 5:
The reviewer commented that EVs will not work without safe charging.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that there are proper resources for project.

Reviewer 2:
The reviewer noted that the project is on track with the available resources.

Reviewer 3:
The reviewer commented that, in the absence of indication to the contrary, this project appears to be sufficiently funded to meet the objectives described.

Reviewer 4:
The reviewer stated that broad based resources and technical expertise are included in the program.

Reviewer 5:
The reviewer commented that funding seems sufficient to meet project objectives.

Acronyms and Abbreviations

°C	Degrees Celsius
3-D	Three dimensional
AC	Alternating current, air conditioning
AMR	Annual Merit Review
ATF	Automatic transmission fluid
B	Magnetic-flux density
BEV	Battery electric vehicle
BH_{max}	Maximum energy product
BP	Budget Period
Br	Residual induction
CNT	Carbon nanotubes
CPC	Capacitive power coupler
CRADA	Cooperative Research and Development Agreement
DC	Direct current
DOE	U.S. Department of Energy
ECCE	Energy Conversion Congress and Exposition
ECV	Electric commercial vehicle
EDV	Electric drive vehicle
EETT	Electrical and Electronics Technical Team
ELT	Electrification Technologies
EM	Electromagnet
EV	Electric vehicle
FFRDC	Federally Funded Research and Development Center
FY	Fiscal Year
GVW	Gross vehicle weight
H	Magnetic-field strength
Hci	Intrinsic coercive force

HD	Heavy-duty
HIL	Hardware-in-the-loop
HESM	Hybrid excitation synchronous machine
HEV	Hybrid electric vehicle
HPC	High-performance computing
HRE	Heavy rare earth
Hz	Hertz
IEEE	Institute of Electrical and Electronics Engineers
IMS	Insulated metal substrate
IPM	Interior permanent magnet
Kg	Kilogram
kW	Kilowatt
kW/l	Kilowatt per liter
kWh	Kilowatt-hour
LCD	Levelized cost of driving
m/s	Meters per second
MD	Medium-duty
MGOe	Megagauss Oersted
MHz	Megahertz
M_S	Saturation magnetization
NA	North American
NREL	National Renewable Energy Laboratory
Oe	Oersted
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PF	Power factor
PHEV	Plug-in electric vehicle
PI	Principal Investigator

PM	Permanent magnet
PTO	Power takeoff
R&D	Research and development
ROI	Return on investment
SCAQMD	South Coast Air Quality Management District
SiC	Silicon carbide
SME	Subject matter expert
SOC	State of charge
T	Tesla
TPG	Thermal pyrolytic graphite
UCC	Ultra-conductive copper
V2G	Vehicle-to-grid
VTO	Vehicle Technologies Office
WFSM	Wound-field synchronous machine

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5. Fuel and Lubricant Technologies

To strengthen national security, enable future economic growth, support energy dominance, and increase transportation energy affordability for Americans, the Vehicle Technologies Office (VTO) funds early-stage, high-risk research. The research will generate knowledge that industry can advance to deploy innovative energy technologies to support affordable, secure, reliable and efficient transportation systems across America. VTO leverages the unique capabilities and world-class expertise of the national laboratory system and works with partners across industry and academia to develop new innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures and better powertrains; and energy efficient mobility technologies and systems, including connected and automated vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement. VTO is uniquely positioned to address early-stage challenges due to its strategic research partnerships with industry (e.g., the U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise. These partnerships prevent duplication of effort, focus U.S. Department of Energy (DOE) research on the most critical research and development (R&D) barriers, and accelerate progress. VTO focuses on research that industry either does not have the technical capability to undertake on its own—usually because there is a high degree of scientific or technical uncertainty—or it is too far from market realization to merit sufficient industry emphasis and resources.

The Fuel and Lubricant Technologies (FT) subprogram supports early-stage R&D to improve our understanding and ability to manipulate combustion processes, fuel properties, and catalyst formulations. This generates the knowledge and insight necessary for industry to develop the next generation of engines and fuels for light- and heavy-duty vehicles. As a result, co-optimization of higher-efficiency engines and high performance fuels has the potential to improve light-duty fuel economy by 35% (25% from advanced engine research and 10% from co-optimization with fuels) by 2030 compared to 2015 gasoline vehicles. The subprogram supports cutting-edge research at the national laboratories, in close collaboration with academia and industry, to strengthen the knowledge base of high-efficiency, advanced fuels and emission control catalysts. The FT subprogram utilizes unique facilities and capabilities at the national laboratories to create knowledge, new concepts, and research tools that industry can use to develop advanced combustion engines and co-optimize with fuels that will provide further efficiency improvements and emission reductions.

Subprogram Feedback

DOE received feedback on the overall technical subprogram areas presented during the 2018 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied.

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year?

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: acs918
Presentation Title: Advanced Combustion Systems and Fuels R&D Overview
Principal Investigator: Gurpreet Singh, U.S. Department of Energy

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:

The reviewer remarked that the program area was adequately covered and well described. This reviewer further recounted several items shown by the presenter: doubling of power density in ten years as related to engine trends; fuel economy (FE) increases as vehicles get larger; and regarding emissions trends, emissions have gone down while the number of vehicles and vehicle miles traveled have increased. The reviewer added that technologies to help the trend, which shows technology penetration, include gasoline direct injection (GDI); turbochargers (used with GDI); cylinder deactivation; engine stop/start; transmissions (six or more speeds); continuously variable transmissions. Overall, the reviewer commented that the program has been successful and continues to be successful due to industry, academic, and government collaboration.

Reviewer 2:

This reviewer asserted that the strategy of Advanced Combustion Systems and Fuels R&D to reduce fuel consumption and emissions through higher efficiency and cleaner combustion-based power was clearly described. Further, the reviewer observed that a clear explanation of the impact of combustion-based vehicle power on the environment was also covered.

Reviewer 3:

This reviewer indicated that yes, the program area and overall strategy are well covered.

Reviewer 4:

This reviewer stated yes.

Reviewer 5:

The reviewer responded positively and observed brief but complete coverage of the program area, including overall strategy. The reviewer added that strategy was well described and seems very good.

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Reviewer 1:

The reviewer affirmed that both near- and long-term R&D are balanced to achieve the overall R&D goals of the program.

Reviewer 2:

This reviewer responded positively; the work with industry affects near-term effectively. There is solid long-term science that greatly contributes to advancing engine knowledge and technology.

Reviewer 3:

The reviewer explained that the program looks at mid-term (advanced spark ignition [SI] research) and long-term (low-temperature combustion [LTC] research), fuel and fuel property effects, and aftertreatment for all combustion types. The reviewer continued that this balance is beneficial to the original equipment manufacturers (OEMs) and is well endorsed by them.

Reviewer 4:

This reviewer responded yes, and noted that a recent update to the Advanced Combustion and Emissions Control roadmap with priorities is integrated into plans. The reviewer also highlighted mixed mode for light-duty (LD) long-term and boosted SI for near-/mid- LD.

Reviewer 5:
The reviewer stated yes.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer commented that yes, the goals were well defined and developed with industry collaboration. Generally, this reviewer described the goals as a significant improvement in engine efficiency while maintaining low emissions and acceptable performance. The presenter showed how the research is successfully approaching these goals.

Reviewer 2:
The reviewer stated yes; it was good to see slides showing the amount of oil saved by investing in internal combustion engines (ICEs). This reviewer further commented that ICE is clearly shown to be relevant long-term.

Reviewer 3:
This reviewer commented that yes, the issues impacting current and future combustion-based vehicles were clearly identified and the challenges to meet future efficiency and emissions goals were adequately described.

Reviewer 4:
The reviewer responded positively and further commented that the challenges were identified and related to the overall system issues.

Reviewer 5:
This reviewer stated yes.

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:
The reviewer reported that the presenter showed the areas of research that the program focusses on, the proposed research road map to reach the goals, and the technologies of focus that will allow that from fuels to engine parts to combustion systems to energy recovery systems to aftertreatment. This is a well thought out program that exemplifies how government and industry collaboration can benefit the United States as a whole.

Reviewer 2:
The reviewer replied yes; plans for developing enabling technologies for cleaner and more efficient combustion engines and fuels are clearly identified and outlined.

Reviewer 3:
The reviewer responded positively and added that plans seem solid and well thought out.

Reviewer 4:
This reviewer stated yes.

Reviewer 5:
This reviewer indicated yes and noted that the emission control R&D slide could have also included challenges of cold start and catalyst light-off.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:
This reviewer stated yes; the targets are carefully developed with industry input and are recently updated. The reviewer described goals as aggressive, but not unreasonable.

Reviewer 2:
The reviewer expressed that it is difficult to gauge progress on such a fine year-by-year timescale for such a large endeavor. However, this reviewer observed that year-to-year trends over the long haul are covered very adequately.

Reviewer 3:
This reviewer referenced an original baseline that had been changed to a more recent engine. The reviewer further commented that the program was benchmarked against the previous year and prior years. The changing baseline made the gains look smaller, but the reviewer explained this is well thought out because it gives a better technological baseline to compare against future research. The reviewer opined that the Program Manager should be commended for making this change because it will give honest, but not inflated, improvements.

Reviewer 4:
The reviewer stated yes.

Reviewer 5:
This reviewer commented that some information was presented.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:
The reviewer indicated yes; the projects seem well chosen to drive transportation technology in useful and effective directions.

Reviewer 2:
The reviewer explained that this program is focused on solving the technological barriers that the VTO office is trying to solve. The projects deal directly with improving the fuel consumption of engines and lowering the energy demands of vehicles.

Reviewer 3:
This reviewer responded positively and asserted that projects like SuperTruck II and Co-Optima are definitely addressing the “broad problems” that VTO is attempting to solve.

Reviewer 4:
The reviewer stated yes.

Reviewer 5:
This reviewer replied yes, to some degree. With respect to Co-Optima, the reviewer commented that near-/mid-term fuel for dilute downsized boosted SI should be the same fuel as that for longer-term mixed mode combustion.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO’s needs?

Reviewer 1:
The reviewer responded positively and was quite impressed with the leadership team, who are effective in leading a collaborative program. The leadership team’s history and expected future are examples of how government should work to improve society.

Reviewer 2:
This reviewer described the program as focused, well managed, and effective. Overall engine efficiency has increased significantly. The reviewer further explained that, thanks to this program, overall understanding of LTC concepts have gone from a science experiment to commercially viable (during parts of the engine map), and low-temperature (LT) aftertreatment that did not look possible now appears to be on the horizon.

Reviewer 3:
The reviewer asserted that the program area is very focused, well managed, and generally effective.

Reviewer 4:
The reviewer stated yes.

Reviewer 5:
This reviewer stated yes.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:
The reviewer asserted that all of the projects are well run and very strong.

Reviewer 2:
This reviewer commented that the program is extremely strong in all technical areas of need. The program manager is good at getting collaboration for industry and academia and it shows in the areas of research and research results. The only weakness observed by the reviewer was that the academic participation, while significant, was not as strong as the industry participation.

Reviewer 3:
The reviewer highlighted close involvement with industry, university, and lab teams as a strength. Further, this develops collaborative efforts toward major technical barriers. This reviewer also noted consideration of both LD and heavy-duty (HD) segments requirements. The reviewer described the tendency to emphasize collaboration to an extent that the overhead of coordination can become significant as a weakness.

Reviewer 4:
Key strengths observed by this reviewer include engagement of wide-range of resources from government laboratories, academia, and industry to tackle problems via a variety of projects and working groups. The reviewer commented that the program area actively seeks out and engages stakeholders to ensure that research remains focused on what all agree is important. However, coordination between labs and leveraging of their different strengths, while much better today than just a few years ago, could still be improved upon, as could encouragement of collaborative research projects between these labs and industry. The reviewer suggested that improved paths towards implementation of government-created tools and methodologies in the commercial sphere should be created and streamlined. Forums like Cross-cut Lean Exhaust Emissions Reduction Simulations and Advanced Engine Combustion memorandum of understanding are excellent examples of ways to share DOE learning with industry and how to provide a feedback mechanism to guide future research so that it remains relevant. The reviewer further indicated that projects like Co-Optima show a degree of coordination between the national laboratories that was sadly lacking just a few years ago.

Reviewer 5:
This reviewer described world-class researchers and research facilities as key strengths. A weakness identified by the reviewer is the ability to turn the fundamental research into something that will impact OEM product, and added that the 2025/2030 time frame is aggressive to impact OEM product plans.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:

The reviewer remarked that the program's projects use technically feasible, but novel and innovative, approaches to solving the problems of increasing fuel efficiency in modern day vehicles while keeping the performance acceptable and the emissions low. Just this year, two auto manufacturers announced that they are producing vehicles using technologies developed in this program, which just 5 years ago were not thought possible due to the technical barriers. This is a testament to the diligence and hard work of DOE Program Manager.

Reviewer 2:

This reviewer indicated yes and thought this is an example of how government agencies should manage and drive technical solutions.

Reviewer 3:

The reviewer stated yes.

Reviewer 4:

This reviewer stated yes.

Reviewer 5:

Although these projects are well reasoned and logical ways to approach the issues being addressed, the reviewer was not exactly sure they represent novel approaches.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:

As noted previously by this reviewer, one of the strengths of this program is the degree to which partners in academia and industry have been combined with government resources to attack the problems at hand.

Reviewer 2:

This reviewer responded positively and observed very effective engagement of industry and university partners including OEMs, Tier 1 suppliers, and other suppliers.

Reviewer 3:

The reviewer commented that the program has engaged partners in industry and academia. The program managers regularly meet with their partners to discuss progress and program goals and are well covered in this area.

Reviewer 4:

This reviewer described collaboration with LD OEMs as strong.

Reviewer 5:

The reviewer stated yes, but suggested better engagement with more universities to provide proper human resources to the industry in the future. This reviewer further commented that support to universities is relatively low-cost compared to national laboratories.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:

The reviewer indicated yes; the combination of collaborative research programs and information sharing forums appeared to be very effective.

Reviewer 2:
This reviewer stated yes and nicely done. Further, very effective collaboration was observed by the reviewer.

Reviewer 3:
The reviewer explained that program managers have set up several avenues for industry and academia to collaborate with them. This collaboration is how they have been successful in achieving their goals.

Reviewer 4:
The reviewer commented yes and noted many interactions and collaborations among national laboratories.

Reviewer 5:
This reviewer remarked that the U.S. Council for Automotive Research and U.S. Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) are good approaches to maintaining awareness for both teams (DOE and industry).

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:
No major gaps were found by this reviewer.

Reviewer 2:
No significant gaps are noted, but the reviewer suggested that an emphasis on eliminating barriers towards early and fast commercialization of tools and learning should be maintained and fostered.

Reviewer 3:
This reviewer reported that in recent years, due to budget cuts beyond the program managers' control, funding to LTC techniques and LT aftertreatment has decreased.

Reviewer 4:
It was unclear to the reviewer how the "kinetically controlled" (KC) combustion mode would be achieved. Further, the reviewer commented that this mode is essentially homogeneous charge compression ignition (HCCI), which has not been working out well in practical application so far.

Reviewer 5:
The reviewer asserted that addressing cycle emissions, including cold start, should be increased.

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:
This reviewer commented that all the topics have been addressed well.

Reviewer 2:
The reviewer stated no.

Reviewer 3:
There were no topics inadequately addressed observed by this reviewer.

Reviewer 4:
This reviewer suggested that greater consideration of promoting ways that combustion-based power can be merged in a more effective way in the trend towards greater electrification of power trains could be pursued, e.g., range extenders, etc.

Reviewer 5:
The reviewer stated yes and referenced prior comments.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:

The reviewer explained that the budget seems adequate to keep the needs in hand, though no one would complain about more funding.

Reviewer 2:

This reviewer noted the cost of lean aftertreatment.

Reviewer 3:

The reviewer highlighted controls as they might aid in application of LTC combustion concepts to enhance stability over the entire operating range of the engine. This reviewer also indicated that integration of multiple alternative fuels in future engines or even more complex hybrid power trains could be potential funding opportunities.

Reviewer 4:

This reviewer remarked that more effort in LTC and LT aftertreatment are needed, and opined that this is the next area of research that will be needed to achieve DOE goals.

Reviewer 5:

Many studies on chemical kinetics were observed by this reviewer, who added that there do not seem to be as many spray studies.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:

This reviewer observed a great approach and stated to keep up the good work.

Reviewer 2:

The reviewer indicated not at this time.

Reviewer 3:

This reviewer stated not applicable.

Reviewer 4:

As LTC becomes more prevalent, this reviewer explained that fuel properties will be more important. Subsequently, the reviewer suggested that DOE needs to engage fuel manufacturers more.

Reviewer 5:

The reviewer recommended making it easier for multiple labs to enter into collaborative research arrangements (e.g., cooperative research and development agreements [CRADAs]) with industry might help reduce barriers and promote better leveraging of the different strengths of the various national laboratories.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:

The reviewer commented to keep going.

Reviewer 2:

The reviewer stated this is not applicable.

Reviewer 3:
This reviewer suggested to continue addressing barriers to production implementation of new ICE technologies.

Reviewer 4:
The reviewer advised to continue the trend towards building collaborative research programs and forums for combining industry, government, and university research.

Reviewer 5:
A larger budget for combustion and aftertreatment was recommended by this reviewer.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0*). In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 5-1—Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ft037	Co-Optimization of Fuels and Engines (Co-Optima)—Overview	John Farrell (NREL)	5-13	3.20	3.30	3.70	3.20	**3.31**
ft051	Co-Optimization of Fuels and Engines (Co-Optima)—Fuel Property Characterization and Prediction	Gina Fioroni (NREL)	5-19	3.50	3.75	3.63	3.63	**3.66**
ft052	Co-Optimization of Fuels and Engines (Co-Optima)—Fuel Kinetics and Simulation Tool Development	Matthew McNenly (LLNL)	5-23	3.33	3.50	3.33	3.33	**3.42**
ft053	Co-Optima Boosted Spark-Ignition and Multi-Mode Combustion, Part 1	Scott Sluder (ORNL)	5-26	3.50	3.50	3.67	3.50	**3.52**
ft054	Co-Optima Boosted Spark-Ignition and Multi-Mode Combustion, Part 2	Chris Kolodziej (ANL)	5-29	3.63	3.50	3.75	3.63	**3.58**
ft055	Co-Optima Boosted Spark-Ignition and Multi-Mode Combustion, Part 3	Scott Curran (ORNL)	5-33	3.33	3.00	3.83	3.00	**3.19**
ft056	Co-Optima—Mixing-Controlled and Kinetically-Controlled Compression Ignition Combustion	Charles Mueller (SNL)	5-37	3.40	3.40	3.50	3.30	**3.40**
ft057	Co-Optima—Emissions, Emission Control, and Spray Research	Josh Pihl (ORNL)	5-43	3.50	3.70	3.40	3.60	**3.60**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
ft062	Characterization of Biomass-Based Fuels and Fuel Blends for Low-Emission, Advanced Compression Ignition Engines (Co-Optima)	Ajay Agrawal (U. of Alabama)	5-47	2.88	3.13	2.88	2.88	**3.00**
ft063	Micro-Liter Fuel Characterization and Property Prediction (Co-Optima)	Ingmar Schoegl (Louisiana State U.)	5-51	3.00	3.00	3.25	2.88	**3.02**
ft064	The Development of Yield-Based Sooting Tendency Measurements and Modeling to Enable Advanced Combustion Fuels (Co-Optima)	Charles McEnally (Yale U.)	5-55	3.25	3.42	3.58	3.42	**3.40**
ft065	Dynamic Species Reduction for Multi-Cycle Computational Fluid Dynamics (CFD) Simulations (Co-Optima)	George Lavoie (U. of Michigan)	5-60	2.90	2.80	2.80	3.10	**2.86**
ft066	Reduced Petroleum Use through Easily Reformed Fuels and Dedicated Exhaust Gas Recirculation	Tom Briggs (Southwest Research Institute)	5-64	2.88	2.88	2.38	3.00	**2.83**
Overall Average				**3.25**	**3.30**	**3.35**	**3.27**	**3.29**

Presentation Number: ft037
Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Overview
Principal Investigator: John Farrell (National Renewable Energy Laboratory)

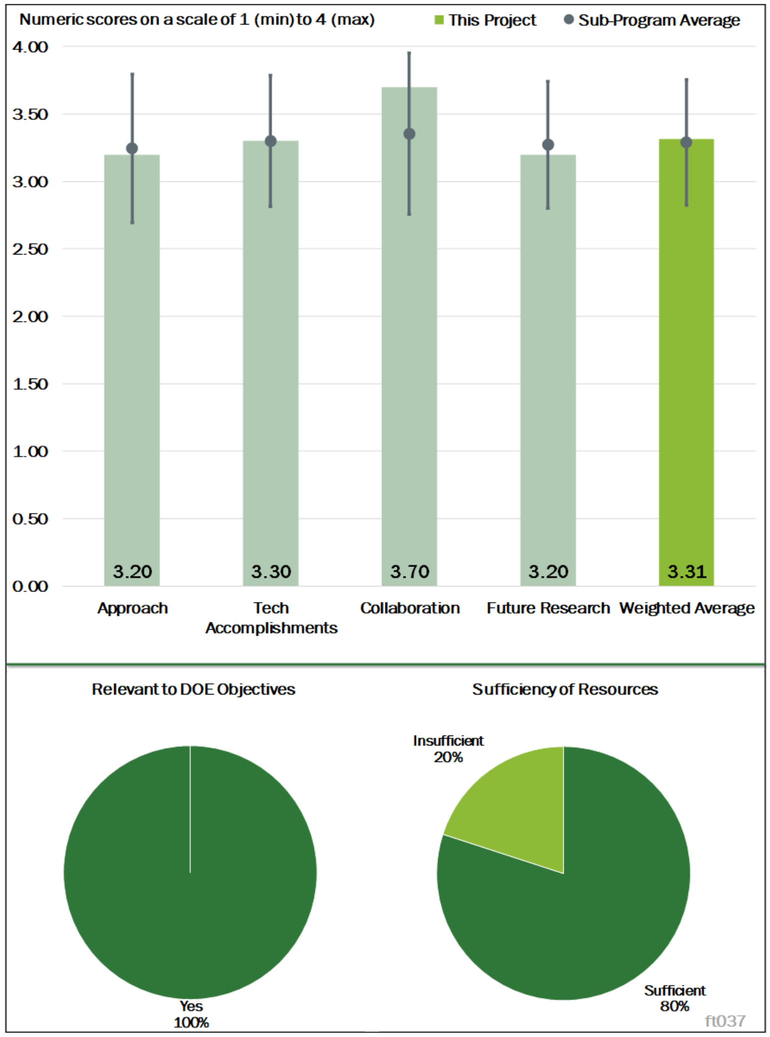

Figure 5-1 - Presentation Number: ft037 Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Overview Principal Investigator: John Farrell (National Renewable Energy Laboratory)

Presenter

John Farrell, National Renewable Energy Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer opined that this is a complex program, involving a broad range of stakeholders, and a very important undertaking. To move towards sustainable global mobility systems, optimizing the power plant and energy carrier systems will be necessary. In the long-term, the reviewer wanted to include the integration, or substitution, of synthetic energy carriers into the fuel system. Yet, the reviewer remarked that this must be done in a transitional way such that legacy fleets are not compromised. Co-Optima has established a collaborative structure with nine national laboratories and representative of stakeholder communities. The reviewer offered that the work is challenging and results in Co-Optima's needing to respond to a wide range of short-term constraints and long-term objectives. The reviewer proposed that the structure the team has put in place should facilitate this complicated task.

Reviewer 2:

According to the reviewer, the overall approach is reasonable for the high-level goals defined in this Overview report. While some of the key technical barriers have been identified, the metrics for gauging successful resolution of the technical barriers are not clearly defined. For instance, the reviewer remarked that emissions have been identified as a barrier/goal. However, no metric/target has been defined for emissions compliance. Considering that Co-Optima is targeting a 2030 engine, the reviewer suggested that at the very least, the engine-out emissions should be at a level consistent with meeting Tier 3 emissions requirements with available technology.

The LD fuel-economy target for Co-Optima, which is currently specified as 10% improvement beyond the 25% gain from business-as-usual (BAU) improvements in engine technology, appeared to be too optimistic the reviewer. The 10% FE improvement is expected to be obtained from changes in fuel properties (e.g., research octane number [RON] and sensitivity) and reduced pumping losses at low loads (advanced compression ignition [ACI] modes). However, the reviewer said that the 25% BAU engine improvements will address some of the same efficiency enablers, specifically compression ratio (CR) and reduced pumping losses, which may pose a challenge to realizing the 10% FE improvement from Co-Optima research.

While electrification is out-of-scope for Co-Optima, the reviewer stated that greater electrification (belt starter generator/integrated starter generator) in conjunction with technologies like continuously variable cylinder deactivation (e.g., Tula) is likely to compete with ACI/KC combustion modes. The reviewer indicated that it may be worthwhile to consider the impact of such technologies, which are expected to be mainstream by 2025, on Co-Optima-based combustion modes and fuel blendstocks.

The reviewer asked that the 2015 baseline for LD engines be clearly defined. At present, the engine configuration or fuel consumption has not been stated explicitly.

Reviewer 3:

This reviewer commented that while the following hypotheses may be true, the program seems to ignore combustion modes or architectures that may yield high efficiency, low emissions such as an engine that operates using gasoline compression ignition (GCI) across a full engine map for LD applications: Central Engine Hypothesis—that there are engine architectures and strategies that provide higher thermodynamic efficiencies than are available from modern ICEs, and new fuels are required to maximize efficiency and operability across a wide speed load range; and Central Fuel Hypothesis—that if we identify target values for critical fuel properties that maximize efficiency and emissions performance for a given engine architecture, then fuels that have properties with those values (regardless of chemical composition) will provide comparable performance. Starting from a clean slate and using “mixed mode” operation, the reviewer asked why GCI is out of the question.

Reviewer 4:

The reviewer commented that the approach is hypothesis driven to find optimum fuel and engine combustion strategies. The approach is logical, but the main barrier is that the predictive models for both fuels and engine combustion studies have not reached the appropriate level that can address the barriers. The reviewer asserted that the results are often limited to the scope of the tested operation. Using the results for broad operating regions of engines will lead to erroneous conclusions. There are too many questions that need answering, while the funding is limited. The reviewer preferred that the project be further focused; thus, meaningful results can be obtained. Otherwise, the reviewer saw that it will be a combination of several fundamental studies.

Given there are different engine platforms and modeling accuracy varies among projects, the reviewer highly recommended that the program directors require “uncertainty analysis” along with “sensitivity analysis” for each of the results from different projects. Thus, the outcome from different projects can lead to informative conclusions. The reviewer noted that many of the projects did not have or presented uncertainty analysis for their findings.

Reviewer 5:

The reviewer stated that a 10% FE-improvement is claimed due to Co-Optima alone. The reviewer inquired as to why the 25% from a base engine is added to the 10% to show a total of 35%. The reviewer found that to be confusing and noted that it gives the impression that Co-Optima is claiming all 35% if one neglects to read the footnote. Also, if the engine improves by as much as 25%, then the reviewer said that the remaining opportunity to get another 10% improvement becomes very, very challenging, given the challenges of mixed-mode combustion.

Pertaining to the central fuel hypothesis, the reviewer stated that fuel structure (molecules) affect aftertreatment operation and performance to a large extent, and perhaps also engine performance (e.g., fuel composition affects cold start performance to a significant effect). The reviewer questioned whether enough work has been done to make a statement about the validity of the hypotheses.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

In 2017-2018, the reviewer commented that there were several noticeable accomplishments: Refinement of the merit function for boosted SI engines, use of pressure-temperature domain to develop a fundamental understanding of auto-ignition and the impact of fuel composition on ignition delay, simulation toolkit development, improved chemical kinetic mechanisms, and spray characterization and particulate emission studies. The reviewer agreed that the aforementioned accomplishments, along with others, demonstrate progress towards DOE’s higher level goals.

Reviewer 2:

While the reviewer disagreed with the research pathways that some of the LD research has taken, the reviewer saw great value in the research that has been done. Research into the beyond-RON and beyond-motor octane number (MON) space is helpful to engine designers and fuel manufacturers alike. It allows both the auto and fuel industries to understand the needs of future engines. This reviewer also saw great potential for the research into how chemical structure impacts fuel properties, and asserted that this research will be of great benefit to the fuel industry.

Reviewer 3:

The reviewer found that the getting this complex organization functioning has been impressive. The organization has been very active in soliciting, accepting, and acting on shareholder feedback. The result is evolving into more tightly focused projects and adjustments in objectives. The reviewer indicated that this complex organization is well into the learning curve of functioning effectively and is actively pursuing opportunities to make it better.

The reviewer agreed with the decision of pursuing mixed-mode combustion for LD engines—KC combustion at light to intermediate loads and transitioning into flame propagation combustion at high load—but expressed surprise that pursuing full map operation with KC combustion was retained for the medium-duty (MD)-/HD activities. It seemed to the reviewer that the constraints that make KC combustion unattractive for heavy load in LD applications also hold true for MD/HD.

The reviewer thought that it will be important for Co-Optima get buy-in from stakeholders that the proposal to introduce a higher RON, higher sensitivity fuel is a starting point, not an end point. The proposed fuel change will preserve the operation of the legacy fleet, enable the immediate introduction of more efficient engines, and will be the basis from which engines using advanced combustion technologies can be introduced into the future.

Reviewer 4:

The reviewer pointed to major progress in the project by characterizing merit functions for different combustion regimes, fundamental understanding for boosted SI operation, and identifying key fuel properties for optimal engine performance. The reviewer saw the integrated results utilizing related projects as missing. Integrated results looking into engine efficiency while meeting emission constraints are further needed. It was not clear to the reviewer how results from different platforms will lead to cohesive conclusions. Multimode operation seems a good option for maximum engine efficiency and minimal engine-out emissions, but much more work is needed.

Reviewer 5:

Multimode SI/ACI is slated to end October 2020. The reviewer wanted to know if this allows enough time to overcome the barriers listed on Slide 13 (transient control, cold operation, combustion noise, etc.). The reviewer opined that the time is not sufficient. For example, there are still significant barriers existing just to commercialize lean, SI flame-propagation combustion because of a lack of an efficient, cost-effective lean exhaust aftertreatment system.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Having worked for over a decade at a national laboratory, the reviewer had never before seen the level of cooperation and collaboration at all levels of the national laboratories as in this program.

Reviewer 2:

The reviewer stated that collaboration is the basis for this entire program and the participants are doing it well.

Reviewer 3:

The reviewer commented that increased collaboration among the participating national laboratories has been one of the strengths of the Co-Optima program. In addition, a concerted effort has been made to schedule and update stakeholders with periodic updates. The reviewer encouraged further interaction with regulatory agencies (California Air Resources Board/U.S. Environmental Protection Agency) to ensure that potential barriers to commercialization of new fuel-blending components are identified early.

Reviewer 4:

The reviewer indicated that the program includes an excellent network of researchers (9 national laboratories and 13 universities). The network is there and different events (Octane Workshop series in July 2018) are well-planned. But, the reviewer pointed out that there are still cases where further collaborations between modeling and experimental groups can be improved. For instance, the project FT065 (computational fluid dynamics [CFD] modeling) will require proper engine experimental data (e.g., cycle-to-cycle residual gas measurements to understand engine dynamics), but the data are not available from the experimental group(s), and this will limit the outcome of the work.

Reviewer 5:

Collaboration is certainly very good across the laboratories and now recently academia. However, the reviewer noted that there are really a very small number of stakeholders who really count, including those who build and sell engines as a business and those who make and sell fuel as a business, and perhaps the fuel distribution and retail industry. Thus, the reviewer encouraged that the input of these two stakeholders should be given more weight.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that it is critical that the Co-Optima members maintain active engagement with the stakeholders to make sure that important barriers are being addressed. The Co-Optima members are doing this now; the reviewer recommended to keep it up.

Reviewer 2:

The proposed research is outstanding and well defined to meet the programs goals, according to the reviewer, who did not see much in the way of things to criticize.

Reviewer 3:

The reviewer stated that the proposed future research is in line with the goal of the Co-Optima program to help develop ACI/mixed-mode compression ignition (MCCI)/KC combustion concepts that are targeted at providing high-efficiency, low-emissions solutions for both light- and HD applications. Transient control and low engine-out emissions are critical for production viability and should be key considerations as go/no-go decisions are made regarding ACI/MCCI/KC combustion modes. While not explicitly stated, the reviewer recommended pursuing fuel spray studies and numerical toolkit development going forward.

Reviewer 4:

The reviewer said that the proposed future research has logical next steps and was pleased to see the emphasis on cold start, transient controls, mode switching, and engine-out oxides of nitrogen (NO_x) and particulate matter (PM) emissions in the future research list.

However, the reviewer noted that the funding is limited so the work needs to further narrowing to reach to productive outcomes unless the project budget is substantially increased. For instance, the project could focus more on engine operation in electrified powertrains because these powertrains will present the main powertrain portfolio for 2030 and beyond. This will limit the scope of the project; thus, the budget will be spent more effectively with more concrete outcomes.

Reviewer 5:

The reviewer advised that more thought should be given to down selecting to one or two practical, scalable fuels of known composition. Further, this reviewer recommended more emphasis on how fuel properties and compositions affect engine combustion performance and exhaust aftertreatment performance.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer remarked that this is a huge but important undertaking. The program is working to balance the introduction of engine and fuel combinations in the near-term and facilitate the introduction of more advanced engines with advanced combustion approaches in the future. The reviewer said that this is an appropriate activity for the government laboratories.

Reviewer 2:

The reviewer noted that the improving existing engine combustion technologies, identifying desirable fuel properties, and developing new biofuels are all expected to contribute to DOE’s goal of petroleum displacement.

Reviewer 3:

The reviewer observed that this program directly aims at DOE’s objectives of lowering petroleum consumption through detailing pathways for engine and fuel manufacturers to use alternative (bioderived) blendstocks to design new efficient engines and fuels.

Reviewer 4:

The reviewer stated that the program aims to increase FE by 10% in LD vehicles (35% compared to model year 2015) and by 4% in HD vehicles. This program includes great efforts on providing clean-energy options, reducing vehicular fuel consumption, and reducing carbon dioxide greenhouse gas emissions.

Reviewer 5:

The reviewer stressed that engine performance and exhaust aftertreatment are certainly dependent on fuel properties (and composition), and so this work is very relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer indicated that resources are sufficient if available on a yearly basis for a timeline that ends way beyond October 2020. In fact, there should be no timeline imposed on projects like this as they benefit industry in bits and pieces on a continual basis.

Reviewer 2:

The reviewer said that the established scope of work is consistent with the budget. The coverage of topic areas seems appropriate.

Reviewer 3:

According to the reviewer, the resources are sufficient to achieve the stated milestones because the project is well-planned.

Reviewer 4:

The funding is sufficient for the proposed work.

Reviewer 5:

Given the scope of this project, the reviewer observed that substantially more funding is required to lead to conclusive and transformative results unless research platforms are reduced. There are too many fundamental problems that need to be understood, and the simulation tools have not reached the capability to be fully predictive.

Presentation Number: ft051
Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Fuel Property Characterization and Prediction
Principal Investigator: Gina Fioroni (National Renewable Energy Laboratory)

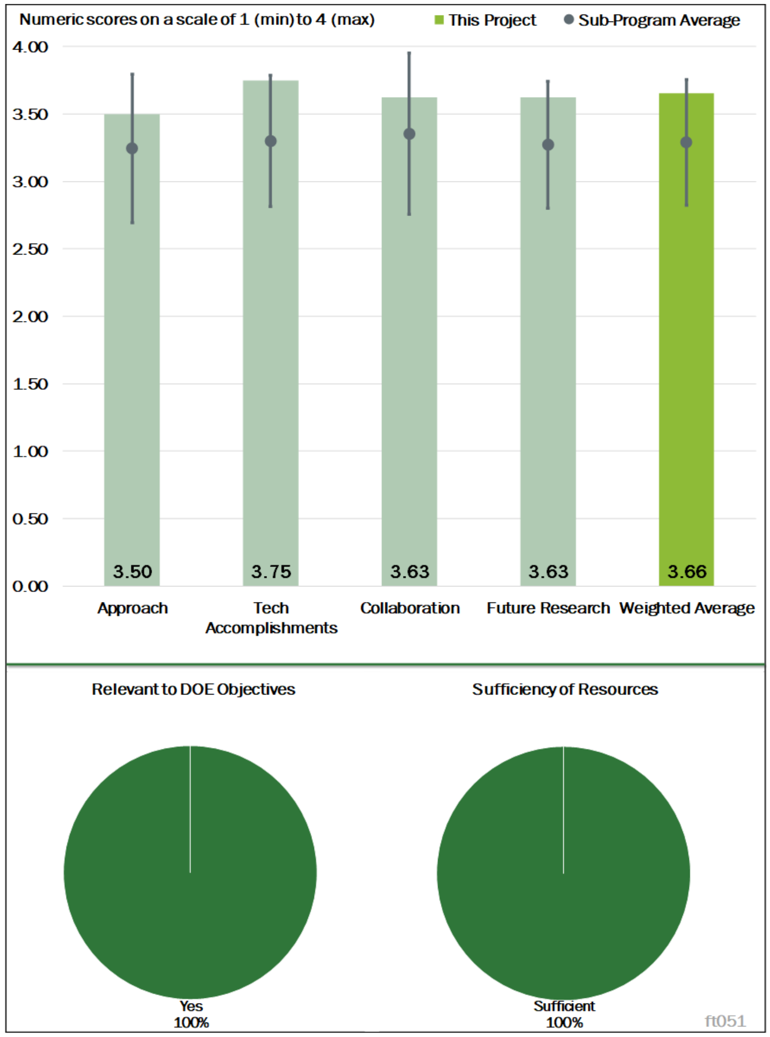

Figure 5-2 - Presentation Number: ft051 Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Fuel Property Characterization and Prediction Principal Investigator: Gina Fioroni (National Renewable Energy Laboratory)

Presenter
Gina Fioroni, National Renewable Energy Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer complimented this project for having developed exceptional methods for better measuring/predicting fuel properties and generating valuable data for mechanism validation. The reviewer stated that the project could be significantly better if the flow reactor can be upgraded to be capable of operating at higher pressure, which is critical to validate reaction mechanisms at conditions closer in ICEs.

Reviewer 2:
The reviewer commented that this is very nice work. The detailed measurement of the connection between the fuel’s chemical structure and its operational characteristics (vapor pressure, auto ignition characteristics and emissions formation potential) is critical, fundamental information. The reviewer stated that it would be wonderful if measurements made could have been made under elevated pressure.

Reviewer 3:
The reviewer found the approach to filling needs for information on fuel properties to be good. Many detailed experiments and simulations must be included. A concern the reviewer had is that with 145 individuals in 86 organizations, it seems that the coordination/communication/status reports required could become a significant workload, taking resources away from actual work.

Reviewer 4:
According to the reviewer, the approach presented is a very systematic methodology for understanding fuel structure and its impact on fuel properties, combustion, and emissions. The fundamental understandings this

project strives to achieve will guide more accurate combustion and kinetic model development required for advanced combustion simulations.

The reviewer commented that measurement of heat of vaporization (HOV) coupled with a mass spectrometer is critical in understanding which compounds vaporize first. The challenge with the results presented is the atmospheric boundary conditions. Fuel injection in direct injection engines occurs at significantly elevated pressures and temperatures, both of which can affect vaporization and ignition characteristics. The other challenge with the presented HOV results is that it is not clear how a fuel spray, with a lean periphery and a rich core, might vaporize. The reviewer proposed that this line of research is probably not appropriate for this project, but would be an interesting experiment.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer pronounced the methods developed to reveal alcohol on Reid vapor pressure and using multiple instruments to quantify HOV on gasoline evaporation as phenomenal. The flow reactor generated valuable data for auto-ignition, kinetic-mechanism development, and validation.

Reviewer 2:

Progress in several areas seems to be very good, according to the reviewer, who also said that important findings are coming out.

Reviewer 3:

The reviewer commented on the very interesting and important results, e.g., ethanol-suppressing aromatic evaporation.

Reviewer 4:

The reviewer reported that the results from the fundamental experiments conducted have identified weaknesses in the kinetic models used for combustion research, especially soot mechanisms. This is an important discovery that will lead to more accurate kinetic models. The combination of the HOV and mass spectroscopy (MS) results show the evolution of different fuel compounds that can drastically impact combustion chemistry. It was not clear to the reviewer how this is impacting kinetic simulations or modeling efforts. The methodology to use less than 0.1 milliliter (ml) of a fuel to estimate RON and octane sensitivity (OS) is very impressive. The OS predication is not as good as RON using the Gaussian process, an explanation of which would have been helpful to the reviewer.

Performing the HOV and MS at elevated pressures might yield different results. The reviewer recommended considering an upgrade to the hardware to tolerate high pressure. The reaction kinetics will change according to pressure so instead of attempting to correlate experiments at atmospheric pressure, it might be more worthwhile to correlate experiments to representative combustion pressures.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, there was outstanding collaboration with universities and OEMs.

Reviewer 2:

The entire Co-Optima program is dependent on strong collaboration, and the reviewer noted that this project appears actively engaged with collaborators.

Reviewer 3:

As expected from the Co-Optima program, the reviewer said that there is significant interaction and contribution from multiple facilities and researchers. This continues to be one of the strongest points of the program. The results of this project can be seen to influence multiple different projects and enable more accurate model development.

Reviewer 4:

The reviewer said that there seems to be good collaboration, but it was hard to judge because there are so many stakeholders. It must be difficult to be aware of projects that should face off. A concern the reviewer had is that with 145 individuals in 86 organizations, it seems that the coordination/communication/status reports required could become a significant workload, taking resources away from actual work.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that the future research is effectively planned in a logical manner, considered the objectives to the overall Co-Optima program.

Reviewer 2:

The reviewer suggested that data at higher pressure would be a great enhancement to the program.

Reviewer 3:

The directions seem to be correct to the reviewer, who said that it is a good idea to upgrade the flow reactor to run at higher pressures; one might expect the chemistry to have pressure dependencies. For example, phi sensitivity of fuels is known to be pressure dependent.

Reviewer 4:

The reviewer stated that the proposed future work addresses the open questions identified in the project update. An improvement would be to upgrade the HOV and MS hardware to tolerate high pressures for more accurate combustion conditions.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer called this work foundational to the modeling efforts in developing new fuels, predicating their properties, and understanding their impact in combustion. This project is instrumental in the Co-Optima program and, as such, is instrumental in the goals of DOE in increasing engine efficiency, decreasing engine pollution, identifying novel and locally sourced fuels, and improving energy security.

Reviewer 2:

As part of the Co-Optima program, the reviewer stated that this project will develop invaluable methods/data for a better understanding of fuel properties, which are crucial for co-optimizing engine and fuel technologies, and definitely support the overall DOE objectives.

Reviewer 3:

This reviewer described Co-Optima, in total, as a very important set of technologies and projects for DOE’s goals of efficiency subject to meeting emissions standards, and energy independence.

Reviewer 4:
The reviewer referenced prior comments and remarked that this project is an important fundamental aspect of the Co-Optima effort.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
If additional resources would allow high-pressure measurements, the reviewer said it would be money well spent.

Reviewer 2:
The reviewer stated that funding is sufficient for most of the tasks involved; however, funding will need to be increased to achieve the higher pressure capability needed for more accurate HOV and MS measurements.

Reviewer 3:
The reviewer said that there are sufficient resources to achieve the stated milestones.

Reviewer 4:
There seem to be a lot of people and facilities involved, according to the reviewer, who commented that the effort seems sufficient.

Presentation Number: ft052
Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Fuel Kinetics and Simulation Tool Development
Principal Investigator: Matthew McNenly (Lawrence Livermore National Laboratory)

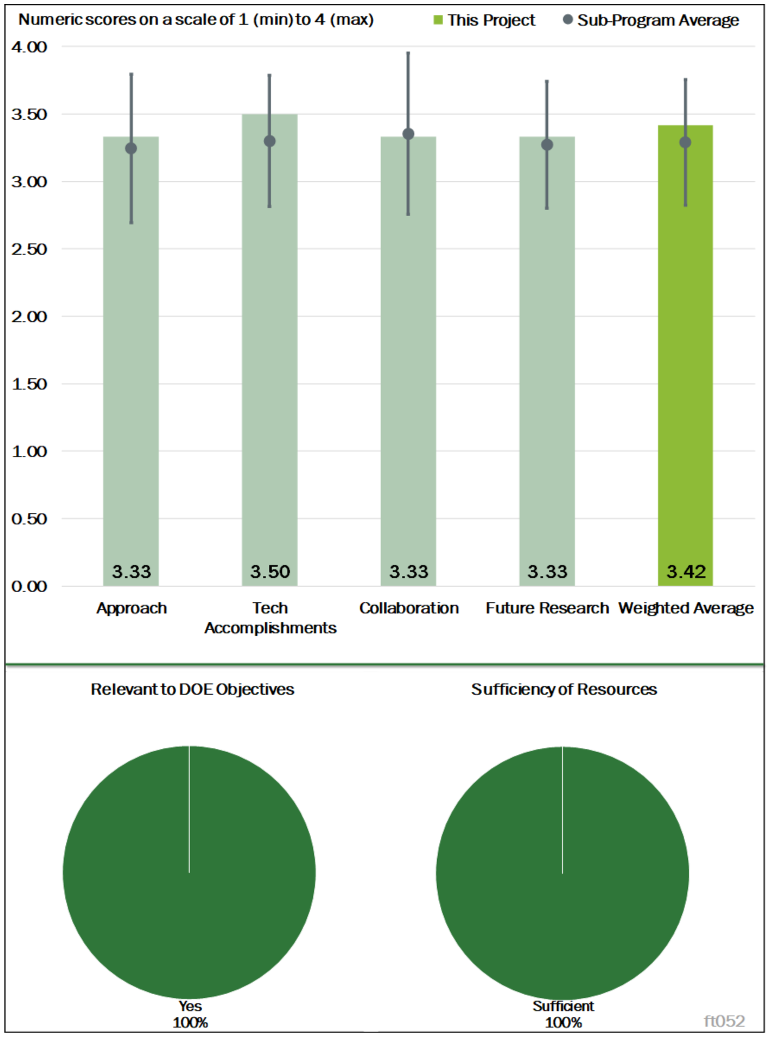

Figure 5-3 - Presentation Number: ft052 Presentation Title: Co-Optimization of Fuels and Engines (Co-Optima)—Fuel Kinetics and Simulation Tool Development Principal Investigator: Matthew McNenly (Lawrence Livermore National Laboratory)

Presenter

Matthew McNenly, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed an outstanding approach to performing the work, and had no further comments.

Reviewer 2:

The reviewer asserted that the project approach is very sound in nature. A systematic evaluation of fuel kinetics and ignition delay times is being done with both experiments and numerical studies. One of the criticisms the reviewer had about the work is the lack of consideration of turbulence in the evaluation of ignition delay times. In addition, some measurement of flame speeds at different pressures will be helpful for model validation.

Reviewer 3:

Overall, the reviewer pointed out that the approach is well-focused on improving the capabilities to predict fuel chemical properties, covering a comprehensive range of fundamental and applied areas. As the project team stated, the relevant engine combustion areas to be tackled include dilute gasoline combustion, clean diesel combustion, and low-temperate and multimode combustion. The reviewer stated that it is important to note that each technical area has its own barriers and requires a specifically tailored approach. The reviewer suggested that the project team should consider clearly laying out the goal, approach, and accomplishments having relevance to each of the above-mentioned areas. For instance, on Slide 6, it is hard to see clearly what approaches the project team is taking to improve the fundament kinetics knowledge/capabilities on clean diesel combustion and multimode ACI combustion.

The reviewer understood that an advanced fuel ignition delay analyzer (AFIDA) provides rapid ignition time delay measurement and can serve as an efficient screening tool. But, it was not clear to the reviewer to what extent it can help kinetic mechanism development considering the physical processes involved. The spray physics in AFIDA may also be different from that in the ACI mode so the value of CFD simulations needs to be clarified. To search for the right fuel chemistry for the multimode ACI/SI operation, the reviewer commented that the project team needs to present a merit function to rank different combinations. In addition to phi-sensitivity and OS, RON may be another parameter that needs consideration. For a proper evaluation, the practical value and the fidelity of the kinetic tools, the reviewer recommended that CFD simulations should eventually be conducted in actual SI, ACI, and diesel engine conditions. To make the knowledge more transferrable to the industry, mechanism reduction is critical and should be addressed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer noted that the team has made good progress since last year. The work on AFIDA is extremely impressive, and it seemed to the reviewer that it is very useful for this work with high through-put. In general, this reviewer was happy with the progress of the project.

Reviewer 2:
The project team has made good progress to address the key project tasks and the overall Co-Optima goals, according to the reviewer.

Reviewer 3:
The reviewer remarked that progress was outstanding and had no further comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer reported the collaboration to be outstanding and had no further comments.

Reviewer 2:
The reviewer found a high degree of collaboration among national laboratories in the project, but encouraged the project team to seek out some industry collaboration. The reviewer noted that there are some industry partners on the external advisory board but did not see an OEM or a fuels company included.

Reviewer 3:
The reviewer commented that the project is well coordinated and has excellent collaborations among national laboratories and universities. The involvement of the Coordinating Research Council and the Advanced Engine Combustion working group is also beneficial. In addition, the reviewer suggested that the project team should consider further strengthening the interactions with OEMs so that the outcomes of the research can be of more practical value and transferrable to industry. Also, the reviewer wanted to see the project team develop closer coordination with the Co-Optima experimental teams on ACI and diesel combustion activities.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said the proposed future research was outstanding and had no further comments.

Reviewer 2:
The reviewer called the proposed future work satisfactory; however, the reviewer urged thinking about including the effects of turbulence in chemistry as that is the missing piece in the puzzle. In addition, the

reviewer asked if the rapid compression machine (RCM) could be converted into a rapid compression expansion machine (RCEM). There might be opportunity for probing species concentration evolution in a RCEM, which can be used for further validation of the species evolution from the chemistry mechanisms.

Reviewer 3:

The further work is overall well-planned to address the remaining technical challenges, according to the reviewer, who suggested adding other areas for consideration, such as developing a merit function for ACI/SI multimode combustion; and incorporating polycyclic aromatic hydrocarbon (PAH) chemistry in the diesel surrogate model, kinetic mechanism reduction, and CFD simulations in actual SI, ACI, and diesel engine conditions.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

By improving the fundamental kinetics knowledge and developing high-fidelity predictive tools, the reviewer highlighted that the project is an important element to support the Co-Optima goals and the overall DOE objectives.

Reviewer 2:

The reviewer affirmed that definitely this project is very relevant to the Co-Optima effort and in general for DOE.

Reviewer 3:

The reviewer reported that the proposed future research was outstanding and had no further comments.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the proposed future research was outstanding and had no further comments.

Reviewer 2:

The reviewer stated that $1.4 million for fiscal year (FY) 2018 shared across various laboratories for both computational and experimental work is reasonable and sufficient for the completion of the work.

Reviewer 3:

According to the reviewer, the resources are sufficient to achieve the milestones and address the technical barriers.

Presentation Number: ft053
Presentation Title: Co-Optima Boosted Spark-Ignition and Multimode Combustion, Part 1
Principal Investigator: Scott Sluder (Oak Ridge National Laboratory)

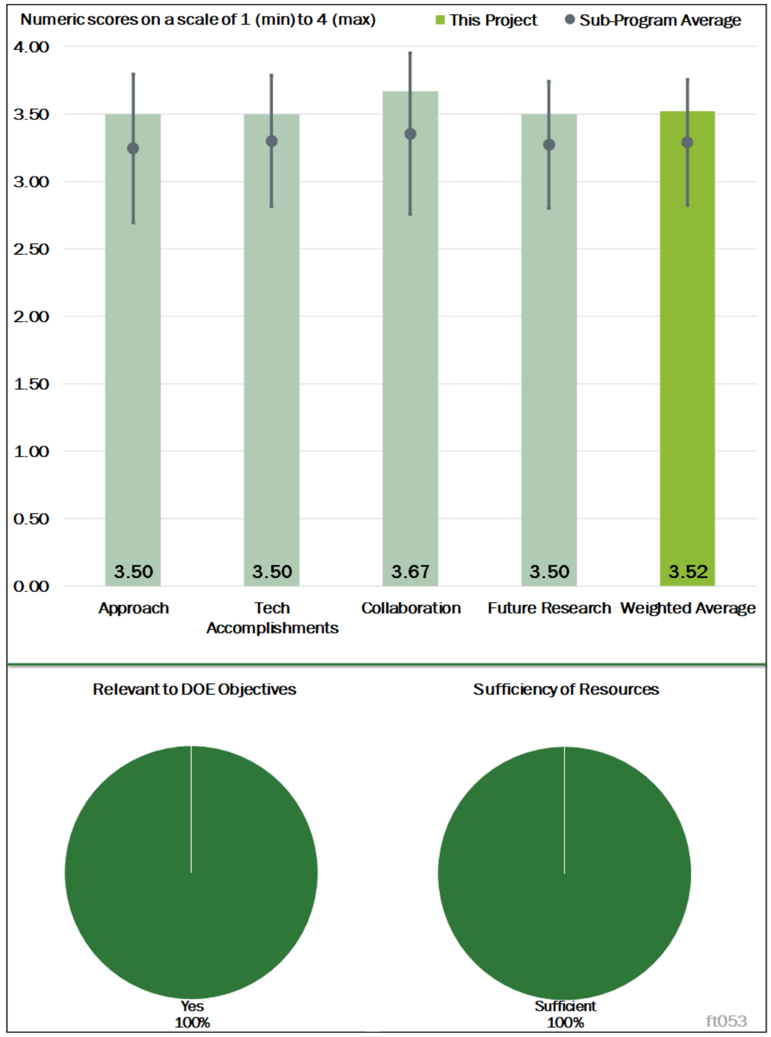

Figure 5-4 - Presentation Number: ft053 Presentation Title: Co-Optima Boosted Spark-Ignition and Multimode Combustion, Part 1 Principal Investigator: Scott Sluder (Oak Ridge National Laboratory)

Presenter

Scott Sluder, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that this work is aimed at increasing the understanding of the impact of high-RON, high-sensitivity fuel on downsized, boosted SI engines, which is a pathway that the LD industry has committed to for the foreseeable future. Thus, the reviewer exclaimed that the potential impact of this work is huge.

Reviewer 2:

The reviewer pointed out that the Co-Optima-boosted SI and multimode SI/ACI efforts focus on an experimental and computational approach to identify fuel properties and allow researchers to use a SI/multimode merit function to choose fuel properties for engines. Once refined, this will be a very useful tool.

Reviewer 3:

The reviewer commented that the project is reasonably designed and planned.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the project has evaluated varying fuel properties in advanced SI engine allowing researchers and engine designers to better understand the relationship between combustion abnormalities, such as knock and fuel properties. While engine manufacturers study this phenomenon in current engines, this research focuses on future engines and technologies allowing the industry to better understand how the changes in technologies are affected by fuel properties.

Reviewer 2:
The reviewer indicated that excellent progress and results have been achieved.

Reviewer 3:
The reviewer remarked that knock is the main barrier to designing a high-performance engine. The knock model is very important for predicting knock onset and hence it is crucial for engine-design optimization. However, the use of knock-intensity extrema in the knock model may be too conservative to be used in the design optimization, and it could lead to a design of less than the true optima. Moreover, all modern engines have incorporated a knock sensor. The reviewer suspected that the knock model without the consideration of the knock-sensor operation may also be too conservative.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
While Co-Optima is a national laboratory-only effort, the reviewer mentioned that researchers have collaborated with OEMs, fuel manufacturers, academia, and national laboratories to perform this research. This work is a great example of how to collaborate with industry and national laboratories.

Reviewer 2:
According to the reviewer, excellent collaboration exists among the laboratories conducting engine experiments, RCM experiments, and simulations over the range of fuels of interest.

Reviewer 3:
The reviewer stated that collaboration exists and the partners are fairly well coordinated.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer suggested that this work should continue for both engine experiments and simulations. The proposal to test the effect of MON at high engine speeds and loads and high-intake temperatures needs to be given high priority.

Reviewer 2:
The reviewer commented that the proposed future research will allow the Co-Optima program to determine the fuel properties needed to enable advanced SI engines.

Reviewer 3:
The plan seemed effective to the reviewer.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer asserted that this project focuses on the impact of fuel properties on down-sized, boosted SI, gasoline-engine performance and so is extremely relevant; it should not be prematurely terminated.

Reviewer 2:
The reviewer remarked that the research is going into information that will be used by engine designers to develop engines that use less fuel, therefore lowering our dependence on petroleum.

Reviewer 3:
The reviewer noted that the project can potentially achieve the DOE goal of Co-Optima.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
Current level of resources should be maintained for the foreseeable future, according to the reviewer.

Reviewer 2:
The reviewer found the research to be on track to meet its goals with the resources it is allocated.

Reviewer 3:
The reviewer said that the team members have sufficient resources.

Presentation Number: ft054
Presentation Title: Co-Optima Boosted Spark-Ignition and Multimode Combustion, Part 2
Principal Investigator: Chris Kolodziej (Argonne National Laboratory)

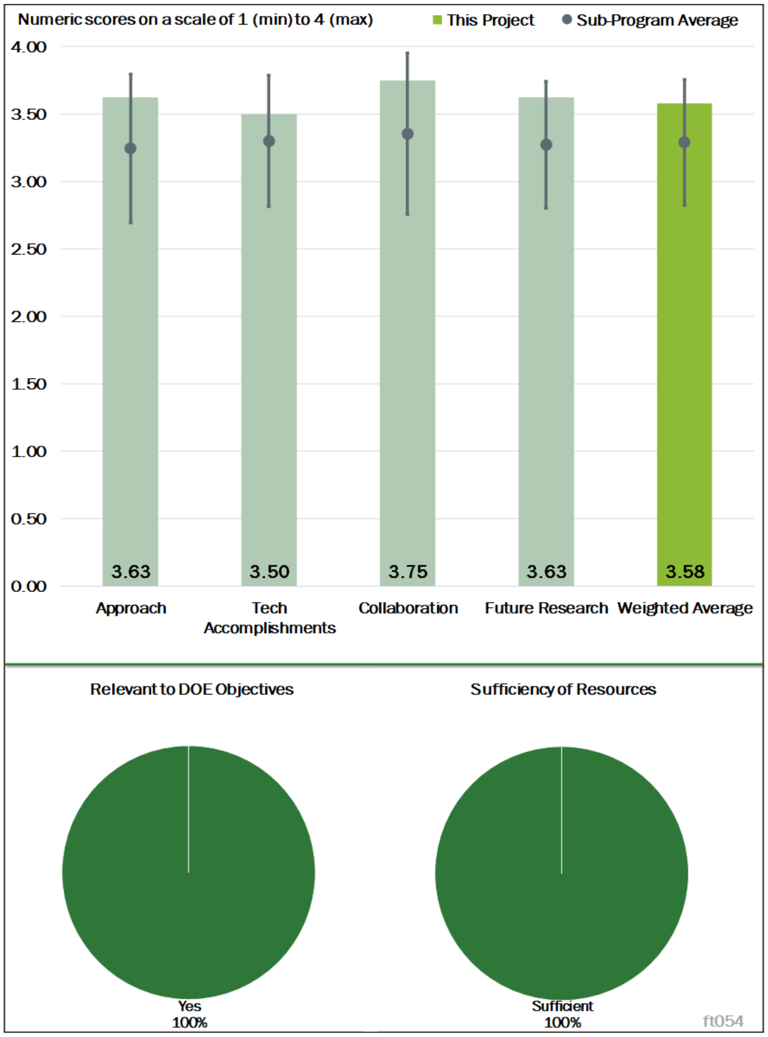

Figure 5-5 - Presentation Number: ft054 Presentation Title: Co-Optima Boosted Spark-Ignition and Multimode Combustion, Part 2 Principal Investigator: Chris Kolodziej (Argonne National Laboratory)

Presenter

Chris Kolodziej, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found the project to be very well-designed as it combines experiments, simulation, and tool (Co-Optimizer) development. The work significantly improves the understanding of fuel impact on engine performance.

Reviewer 2:

According to the reviewer, the approach is on target with emphasis being placed on the correct areas (fuel property effects on auto-ignition, simulation support, using the Co-Optimizer, and using the Merit Function to grade candidate fuels).

Reviewer 3:

The reviewer noted that the project is gathering octane-relevant data with well-designed experiments at conditions relevant to boosted SI engines.

Reviewer 4:

The reviewer commented that the experimental approach in this project is logical and looked into the effect of fuel properties on knock intensity and auto-ignition. The approach for the uncertainty and sensitivity analysis is very valuable and can be used in other projects as an example. However, the approach in the Co-Optimizer (simulation) area needs further thinking. Two major items to consider are that the Optimizer can produce the proper outcome only if there are enough data used to cover all major nonlinearities, and the process for knock/auto-ignition is not Gaussian for broad engine operation. The reviewer asked how residual gas composition/fraction and cyclic variability effect are seen in the defined merit on the presentation slides.

In exhaust-gas recirculation (EGR)-diluted combustion (barrier 1), the cyclic variability and combustion stability are major concerns. It was not clear to the reviewer how this is addressed in this project because the focus is mostly on knock and auto-ignition.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the work on RON and HOV is providing new knowledge and increased understanding of how these fuel properties affect engine performance. Knock-correlation work with various knock metrics has also provided new information that industry can use. The virtual constant-pressure flow rig (CFR) is a clever approach and will save time and resources in the long run.

Reviewer 2:

The reviewer found that significant progress has made in learning how HOV and RON affect auto-ignition. The experiments were very well-conceived. CFD helped to explain the transition between knocking and normal SI combustion. Co-Optimizer is a useful tool supporting decision making.

Reviewer 3:

The reviewer complimented the project as being some nice work, and especially liked the virtual CFR and the CFR with compensation for HOV and boost.

Reviewer 4:

The reviewer commented that CFD model validations and understanding knock in boosted SI operation are the major accomplishment of this project. The project also provides helpful knowledge for understanding the tradeoffs among engine performance, fuel cost, and uncertainty. However, the reviewer stated that the project shows limited accomplishments in the areas of robust lean-burn and EGR-diluted combustion control and determining factors limiting LTC and method to extend limits for the barriers identified as the program objectives.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that there was excellent collaboration among national laboratories and with OEMs, universities, and energy companies.

Reviewer 2:

According to the reviewer, there are lots of collaborations; involving the right kinds of skills and facilities in an effective way. The reviewer said that it was nice to see experimentalists and modelers in close proximity programmatically.

Reviewer 3:

The reviewer said that collaboration with many relevant organizations exists.

Reviewer 4:

The reviewer pointed out that there exists a strong collaboration within the Co-Optima team. The reviewer noticed that the requests from this project team for more data/inputs from experimentalists, as these are essential for the Co-Optimizer to generate quality outcomes. Similarly, further data are required for proper training of the artificial neural-network model for covering broad conditions.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer especially liked the idea of a boosted CFR to measure RON/MON at more boost-relevant conditions.

Reviewer 2:
The reviewer indicated that the proposed future work is laid out in a logical manner, with little risks.

Reviewer 3:
The reviewer asked whether one or two of the high-RON, high-sensitivity candidate fuels being tested can be recommended as being the best overall fuel for downsized, boosted SI engines.

Reviewer 4:
The proposed plan includes important remaining topics to be studied. The reviewer noticed only 3 months left in the project. Finishing all the proposed future research within 3-month timeframe would be very difficult.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer asserted that the project aims to increase efficiency of ICEs by providing better understanding of combustion in SI engines and generating an innovative Co-Optimizer tool to minimize fuel consumption and cost. This directly addresses the DOE objective to reduce vehicular fuel consumption and improve energy security.

Reviewer 2:
The reviewer said that high engine efficiency is targeted for downsized, boosted SI engines, a pathway that the LD industry has committed to. So, much of this work can directly be implemented in the very near future.

Reviewer 3:
The reviewer found the work to be well-aligned with the overall goal of Co-Optima. This project advances our knowledge of fuel-engine co-optimization, which supports the DOE objective of improving efficiency.

Reviewer 4:
The reviewer mentioned that Co-Optima goes to the root of DOE's energy independence and efficiency missions while considering limits on emissions.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer noted that there are sufficient resources to achieve the stated milestones.

Reviewer 2:
The reviewer found the resources to be sufficient.

Reviewer 3:
The reviewer commented that there are sufficient resources as long as a strong collaboration exists with experimental groups in the Co-Optima program to provide the required experimental data for this project.

Reviewer 4:

Resources seemed appropriate, although more funding might accelerate the results. OEMs are already near the time for committing designs for production, and that is near the time that Co-Optima is scheduled to end so the data cannot come too soon.

Presentation Number: ft055
Presentation Title: Co-Optima Boosted Spark-Ignition and Multimode Combustion, Part 3
Principal Investigator: Scott Curran (Oak Ridge National Laboratory)

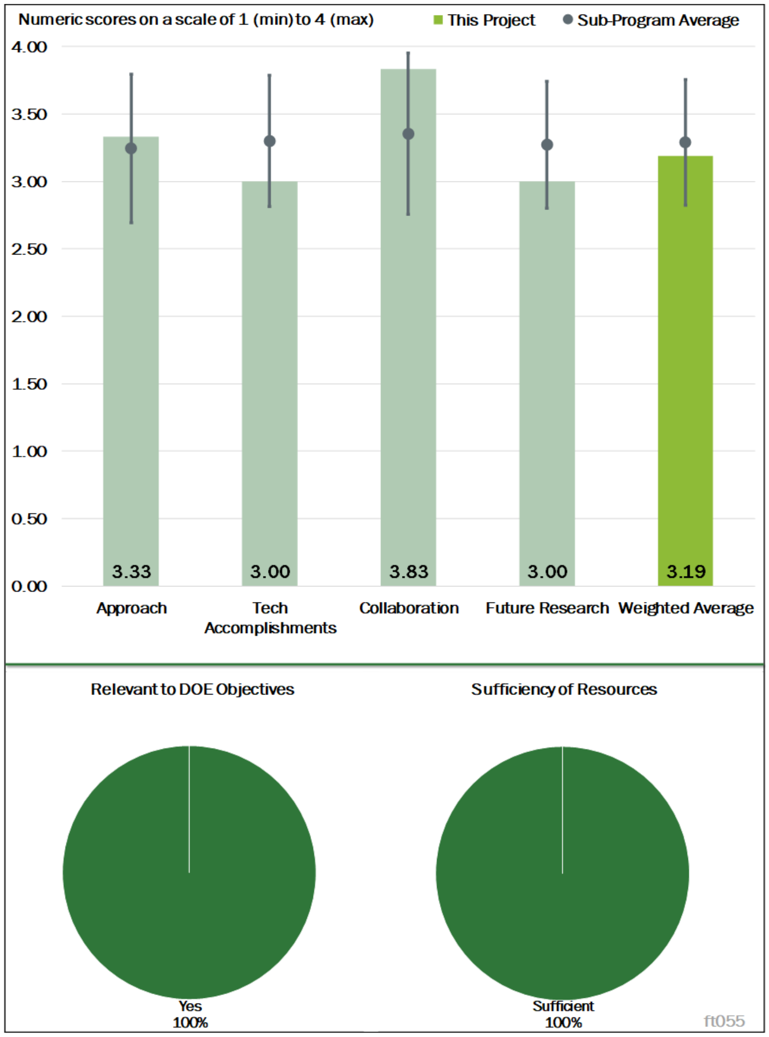

Figure 5-6 - Presentation Number: ft055 Presentation Title: Co-Optima Boosted Spark-Ignition and Multimode Combustion, Part 3 Principal Investigator: Scott Curran (Oak Ridge National Laboratory)

Presenter
Scott Curran, Oak Ridge National Laboratory

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer indicated that the team is performing well in this project with a healthy blend of experimental work and numerical computations. This is a well-designed project.

Reviewer 2:
The reviewer stated that employing measurements in metal and optical engines and using CFD modeling are good approaches to enhancing synergistic work performance and effectively addressing the technical barriers of the research scope.

Reviewer 3:
In general, the reviewer noted that all subprojects have identified key barriers and have worked towards addressing those barriers. As the work on multimode/ACI combustion modes progresses, the reviewer offered a few suggestions. Firstly, for ACI modes that rely on high intake temperatures, there is a need to demonstrate that the high temperatures can be achieved using internal EGR/hot residuals. Alternatively, the team needs to account for the energy required to provide the hot air temperatures while estimating the efficiency of the ACI mode. Secondly, as transient operation for multimode/ACI combustion is investigated, the reviewer said that it is also important to demonstrate that the ACI-mode enabling conditions (e.g., air temperature, valve timing, valve lift, and variable compression ratio [VCR]), can also be achieved in realistic time durations (few cycles instead of few seconds). Thirdly, as the various ACI combustion modes are investigated, especially those involving lean combustion, engine-out emissions should be taken into account while calculating efficiency improvements (e.g., catalyst regeneration, nitrous oxide emissions). Past DOE/industry projects have demonstrated high thermodynamic efficiencies for ACI modes, but have been limited by the inability to meet criteria emissions. Lastly, the reviewer remarked that sensitivity studies for ACI combustion modes should also include variation in fuel composition for a given specification to capture best- and worst-case market fuels. In other words, information on how tightly a fuel specification would need to be controlled would be

extremely valuable in determining the feasibility of a combustion mode plus fuel combination. A blendstock by itself may be affordable, scalable, sustainable, and compatible, but if the finished fuel needs to be controlled to very tight specifications, then it may not be commercially viable.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer praised this project as having made good progress over the past year and summarized some of the notable accomplishments of the project, including engine-out soot measurements as a function of particulate matter index (PMI) for nine different fuels. The work that is focused on variations in spray characteristics that influence particulate emissions but are not accounted for by PMI is valuable and should be pursued further. As the blendstocks are varied, the reviewer suggested that the variations in combustion stability/duration should also be tracked, especially for ACI modes to understand the sensitivity to variations in fuel composition. Production applications need to operate without knowledge of fuel composition; thus, the ACI combustion mode needs to be robust to account for variations in fuel composition. The reviewer thought that the quantitative wall-wetting diagnostic technique is a powerful tool for studying soot production. Investigating the impact of fuel composition on wall wetting and soot production for similar operating conditions would be valuable information for assessing the suitability of different blendstocks for SI/ACI combustion modes. Additionally, the reviewer said that any investigations during transient operation that can help minimize soot production during transient maneuvers would also be very valuable. The reviewer had a comment about determining the temperature variation between the maximum temperature that allows knock-free, high-load SI operation and the minimum temperature that enables low-load HCCI operation. While this information is useful, the high load investigated is not high enough. For multimode operation, ACI modes are expected to be coupled with downsized boosted operation. While 9-bar indicated mean effective pressure (IMEP) may be a high load for naturally aspirated (NA) applications, it is only a medium load for downsized boosted applications. If the ACI modes need to be used in conjunction with NA SI combustion, the reviewer explained that this would drive a larger engine size and would come with associated friction losses. The aforementioned accomplishments are in line with the overall goals of the Co-Optima program.

Reviewer 2:

According to the reviewer, overall technical accomplishments are in line with project expectations. In terms of CFD modeling, it was unclear to the reviewer where the flame-speed data at higher pressures are made available for the G-equation flame propagation model for the exotic Co-Optima fuels. This is crucial for knock predictions. The two-step VCR engine for enabling multimode is good work for the future and will only be meaningful with transient cycles. In some sense, the reviewer opined that the project gives a feeling of mixing two OEM approaches: the Nissan VCR engine approach and the Mazda SKYACTIV-X approach.

Reviewer 3:

The reviewer mentioned that progress in addressing technical barriers seems to be rather slow compared to previous years. The figures in Slide 18 indicate that change in temperature (dT) alone is not enough to characterize multimode operation. The reviewer offered that the suggestion of another parameter seems to be necessary. Also, the dT metric seems to be a function of the CR, and the researchers even seem to intend to explore high CR engine operation. However, the reviewer opined that the current scope and approach of multimode combustion are clearly limited by the range of CR of interest (that of conventional gasoline engines). This will significantly limit the application of the multimode combustion concept.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer called having Ford, GM, and Toyota in the team as fantastic and noted that collaboration with other national laboratories is also a plus. This is truly a very cooperative effort.

Reviewer 2:

The reviewer found excellent collaboration among participating national laboratories as well as industry partners. The reviewer said that it is worth noting that coordinating the activities across multiple teams/researchers requires a lot organization and the effort is worth applauding.

Reviewer 3:

The reviewer commented that the collaboration was well-organized based on assigned tasks, though the reviewer encouraged more involvement by industry partners.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The project has made good progress thus far and the reviewer encouraged continuation of several of the ongoing efforts. For the Sandia National Laboratories (SNL) mixed-mode/SI work, the reviewer said that, in addition to lower RON fuels, the impact of low MON should also be investigated to determine the effect on load range. As CR is increased for enabling both ACI modes and efficient SI combustion, engine operating conditions under high-speed, high load conditions with hot intake air temperatures may be closer to MON operation. For the Argonne National Laboratory (ANL) multimode work, the reviewer suggested that as new fuel properties are determined/defined that enable ACI operation, care should be taken that in a multimode engine, the same fuel needs to be used for high-load SI combustion as well.

While the scope of work is limited to low technology readiness levels (TRLs), the reviewer asserted that the project should keep practical considerations such as aftertreatment requirements and transient controls in mind while analyzing results and assessing the feasibility of the combustion concepts being proposed.

Reviewer 2:

The reviewer found that adding lower RON fuels to the test matrix is encouraging as are expanding efforts on load transients, start studies on cold-start effects, and developing and validating a CFD approach for lean SI combustion. The reviewer had questions about what the major factors would be to validate in lean SI engine simulation, and what kinds of parameters to consider to identify influential fuel properties for multimode ACI operation. Some of the tasks seem to be tough to achieve, e.g., to identify/define new fuel properties that impact engine performance under ACI operation with the nine fuels considered. But the reviewer still encourages these efforts.

Reviewer 3:

The reviewer remarked that it is highly important to conduct transient work (at least snap throttles at various speeds) to study the transition between ACI and SI, which will be at different CRs. This work is critical for OEMs to adopt this technology. The reviewer noted that the controls work is non-trivial; it is very important that there is a gentle transition between the regimes without noise, vibration, and harshness and/or misfiring/knocking events. In addition, the emissions characteristics during the transients will be important for certification.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer commented that achieving the tasks suggested for future research would definitely support the DOE objectives for several reasons: knowing ways to improve ACI operation model will be possible; developing optimal fuels for specific engine operation mode will be possible; and understanding what the major limiting factors/road blocks are in improving gasoline engine efficiency in ACI/SI mode will be possible.

Reviewer 2:
The reviewer stated that the investigations being undertaken as part of this project are in line with the overall DOE goal of petroleum displacement.

Reviewer 3:
The reviewer affirmed that this project is highly critical to the Co-Optima goals and the DOE objectives in general.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
According to the reviewer, the FY 2018 budget looks sufficient for the different tasks proposed in the project.

Reviewer 2:
The reviewer found the funding to be sufficient for the proposed work.

Reviewer 3:
Experimental resources seemed to be enough to the reviewer to perform the suggested tasks. However, the reaction mechanisms and fuel properties prediction model are mature enough to be reliably used in multi-component fuel CFD modeling.

Presentation Number: ft056
Presentation Title: Co-Optima—Mixing—Controlled and Kinetically-Controlled Compression Ignition Combustion
Principal Investigator: Charles Mueller (Sandia National Laboratories)

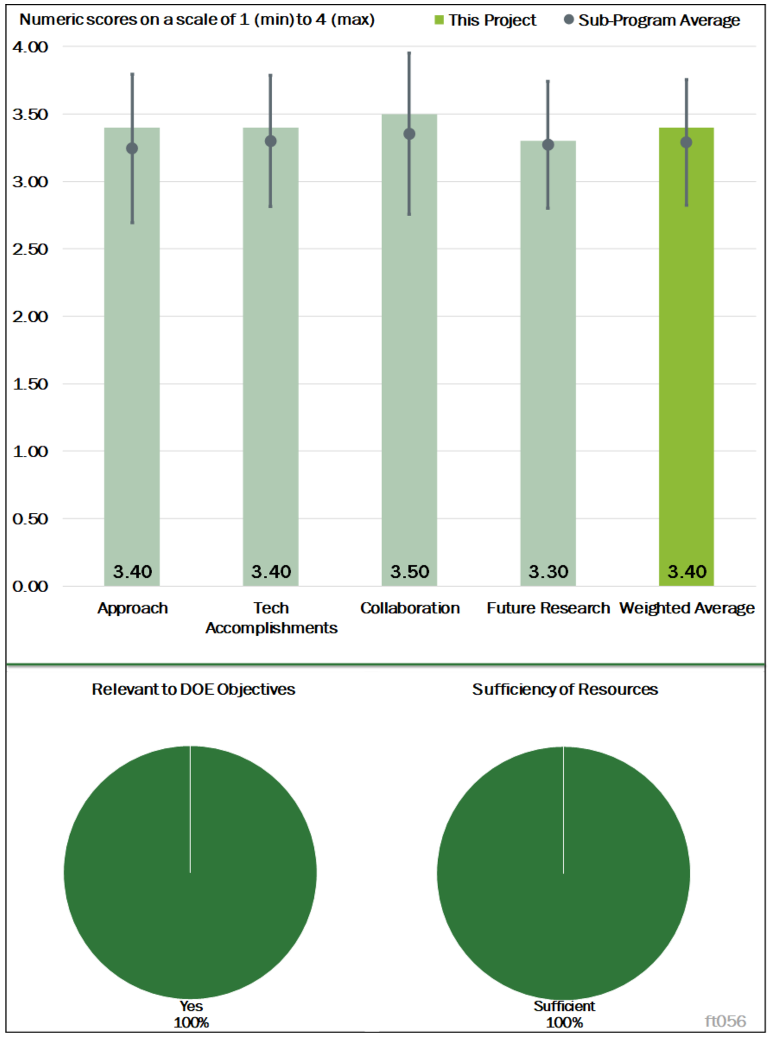

Figure 5-7 - Presentation Number: ft056 Presentation Title: Co-Optima—Mixing—Controlled and Kinetically-Controlled Compression Ignition Combustion Principal Investigator: Charles Mueller (Sandia National Laboratories)

Presenter
Charles Mueller, Sandia National Laboratories

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer stated that the project is very well designed using multiple diagnostic and simulation tools for an in-depth understanding of fuel spray and mixing controlled compression ignition.

Reviewer 2:
The reviewer found the project to be well-designed and well-planned.

Reviewer 3:
According to the reviewer, this presentation did a very good job of showing how the different experimental programs within Co-Optima fit together to cover the overall objectives of the program. The reviewer stated that it was an excellent presentation, but it will be difficult to offer detailed comments about any of the projects covered because they were covered at such a high level.

Reviewer 4:
It was obvious to the reviewer that trying to pack five projects into one review is too much. Generally, what could be conveyed in the review time showed that most of the projects have a good approach. The reviewer noted that the Advanced Compression Ignition: Fuel Effects (ACI-F) project seems tightly aligned with LD, while the MCCI project seems aligned with HD, and the spray projects are cross-cutting. The reviewer trusted that each project is coordinating with industry input to help guide the approach with respect to relevant industry constraints, but with a future-looking orientation.

Reviewer 5:
The reviewer commented that the studies in the individual tasks are generally good and are addressing various technical barriers. However, the reviewer described the overall project as somewhat messy. It seemed to this

reviewer that the goal is to look at fundamental spray/fuel interactions and then how that process ends up impacting the combustion process. It is not clearly linked as presented, and it seemed to the reviewer as if there is just too much going on in too many directions. The reviewer expressed some concern that the projects will end up going in different directions without consistent datasets that we can use to derive lessons that will help with development of future engines or fuels.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer praised the overall progress of the individual projects as excellent, and indeed it appeared to the reviewer to be contributing to the objectives of Co-Optima relative to the effects that fuel characteristics can have on the various phenomena associated with engine operation.

Reviewer 2:

The reviewer commented that the principal investigators (PIs) have made excellent progresses on all subtasks. The mixing controlled combustion (ducted fuel injection [DFI]) is quite interesting, but the reviewer was not sure how to implement it on ICEs. Hopefully, the PI can come up with a solution.

Reviewer 3:

The reviewer said that the liquid extinction images of two fuels show very distinct differences in spray structure and penetration. The explanation that this is based on distillation effects might not be complete because the two fuels could have very different surface tensions and viscosities, which will lead to atomization and resulting droplet sizes.

Reviewer 4:

The reviewer summarized and commented on the technical Accomplishments for ACI-F as follows: According to the milestones, this project seemed to be on task and doing well. The work seems very detailed and thorough. The reviewer believed that the use of very high intake-manifold temperatures is for kinetic understanding and less about engine operation performance. Using relevant engine conditions for kinetic validation and development is extremely good. Many times, kinetic models are validated with conditions that are just not relevant to today's engine states. The reviewer requested that the project team is sure that the conditions used in this work are aligned well with high power density engines for best use across industries and markets.

Regarding the technical accomplishments for MCCI, the reviewer reported that these are some of the most interesting and potentially breakthrough work in the DOE portfolio. These accomplishments have the potential to disrupt the NO_x-soot trade-off and shift energy and commercial sectors. Progress seems to be moving towards in-engine understanding with the optical engine experiments and in-cylinder soot quantification. If this is going to be disruptive, the reviewer said that an enormous amount of work needs to happen regarding design parameters, sensitivities, durability, fuel effects, deposits, materials, and thermal/mechanical fatigue. Validation of many things needs to happen before this goes to production.

According to the reviewer, mixing controlled combustion is dominant and will not be displaced by KC combustion concepts for a multitude of technical, scientific, and economic reasons. More DOE effort needs to be pushed towards mixing controlled combustion system scientific understanding, computational modeling, and technology generation. The reviewer urged the project team continue strong support of this DFI project and consider increasing the budget and scope. It was refreshing to the reviewer to see MCCI technology work because ACI has been a focus for a very, very long time.

Regarding the technical accomplishments for spray/combustion—optical imaging (SCO), the reviewer pointed out that the milestone chart says things are pending so it seems that this is a little behind. This fundamental spray work helps everyone in engine combustion because sprays are the starting point for today's fuel-air mixtures. The building of a new, high-flow vessel is no simple task. The reviewer found this new capability to be excellent because it allows for high temperatures and pressures to be achieved, which are needed to be relevant to today's high-power density engines. It was good progress.

As far as technical accomplishments for the Sprays: X-ray Imaging (SX) project, the reviewer remarked that again, this spray-related project is making good progress. It is no small task to get functioning sprays at relevant boundary conditions for high-fidelity imaging. The reviewer suggested considering allocating more funding to help upgrade the X-ray spray capability and asked if putting a combustion vessel at the X-ray facility has been considered.

Regarding the technical accomplishments for the Sprays: Simulation (SS) project, the reviewer had difficulty assessing progress for this project, but getting better thermo-physical properties into three-dimension (3-D) CFD combustion simulations is outstanding. This is a real gap in present simulation codes used within industry, specifically concerning the fuel and spray processes. The reviewer encouraged the team to continue and to make sure that code or sub-models that are developed can be integrated by the industry into relevant CFD codes.

The reviewer was not sure about DOE's playbook on intellectual property and commercialization in this software/model/code area. The reviewer wanted to know if these code developments are open source and whether DOE or the laboratories wish to monetize the output of these simulation products. The reviewer asked if there is a guideline on how these things will happen because taxpayer dollars are used to develop these simulation tools. The reviewer was thinking about the path that the Lawrence Livermore National Laboratory (LLNL) Zero-RK is taking and was not sure if industry could obtain the better chemistry solver for their own use.

Reviewer 5:

The reviewer stated that there appears to be decent progress on activities in all of the tasks, but it was completely unclear what work is connected to Co-Optima as compared to other work. For ACI-F, the same results were presented both as Co-Optima results as well as results from the combustion activity funding. The reviewer wanted to know what work is actually related to Co-Optima and whether it is distinct in some way from the combustion funding. Also, the reviewer inquired whether the fuels investigated here are consistent with those from the SI and mixed-mode Co-Optima tasks. Another question from the reviewer dealt with knowing if there is more definition of the fuel properties and chemistry available as the reviewer could not really tell from the material presented.

For the MCCI work, the DFI is technically interesting, but it did not seem to the reviewer at all related to Co-Optima at present. From a practical standpoint, it also seems very problematic for durable manufacturing; small features like this in the combustion chamber tend to erode and break under the thermal and mechanical stresses of combustion. It seemed to the reviewer as if this work should be funded elsewhere in the DOE and should step back to consider some basic mechanical and thermal issues before going forward with combustion development.

The SCO work was quite interesting to the reviewer, who wanted to see more focus in this area; there have been questions on how biofuels and other non-conventional fuels behave in sprays for decades, and this is something that ought to be understandable with today's diagnostics and simulation tools The reviewer would argue that the spray work should be the biggest part of this task right now, and the engine combustion work should be used primarily to generate data for comparison and framing of the spray studies. Once we understand the spray better, more effort can be put into the combustion systems.

As for the SX, the reviewer said that it coordinates well with the SCO work and the same comments apply. The reviewer remarked that it would be good to know how the SS work integrates with/coordinates with/duplicates the other modeling tasks funded through the VTO. It was difficult for the reviewer to tell what is different here from what we saw in other presentations from the VTO modeling teams.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer found very impressive collaboration among the different laboratories and the stakeholder industries.

Reviewer 2:
The reviewer said there was outstanding collaboration with OEMs, universities, and among national laboratories.

Reviewer 3:
Collaboration seemed excellent to the reviewer, who commented that there was enough collaboration to have one PI present five projects worth of material so that seems to be good justification. Also, much of this research is regularly seen at other review presentations with good discussion and engagement.

Reviewer 4:
The reviewer remarked that there was good collaboration, and the partners participate and are well coordinated.

Reviewer 5:
It was not clear to the reviewer that there is really any coordination across the project team; the studies do not seem particularly supportive of each other or building on each other. In general, the reviewer stated that the various Co-Optima thrusts appear to be doing a lot of overlapping work that could be better integrated and coordinated.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
According to the reviewer, the future work is planned in a logical manner to realize the proposed targets; there are no major risks.

Reviewer 2:
The plan seemed effective to the reviewer.

Reviewer 3:
It was difficult for the reviewer to answer questions like this because the presentation covered multiple projects at a very high level. It seemed to the reviewer that the projects are being effectively carried out and the planned future work addresses the important barriers.

Reviewer 4:
The reviewer had no problems concerning proposed future research for four of the five projects as they are either fundamental, cross cutting, or potentially disruptive. The ACI-F project seemed well-aligned with the Co-Optima LD focus, but the reviewer was very unsure that ACI has a significant place in future engines regardless of the market or class of engine. It seemed to the reviewer that the LD OEMs have pushed for a fuel that is optimal for boosted SI and ACI, which may be too near-term in focus and potentially dictating physics. As the power system for transportation changes, the reviewer opined that there are continued, non-combustion technologies eroding the area of opportunity for ACI. The reviewer urged continuing research towards a

future-looking state, but with active industry engagement about the entire power system constraints. Engines will be turned off or only operated at the most efficient location. There are many things that interact with combustion, and ACI needs fully accounting for these likely future interactions. According to the reviewer, a good example is that once electrification, hybridization, and near-zero NO_x emissions regulations come into place, ACI must provide a more efficient, lower cost, as capable, and synergistic solution than other combustion concepts in order to be viable.

Reviewer 5:

The reviewer liked the overall plans for the SCO and SX tasks; using these diagnostics to dive into how these new fuels behave in sprays and what that does to mixture formation is fundamental and essential to the co-development of fuels and engines. The two engine tasks (ACI-F and MCCI) seem weakly planned. It was unclear to the reviewer how the ACI-F task is unique compared to the boosted SI and mixed mode work being performed, and it seemed overly split between some fuel testing and working on surrogate mechanisms that the reviewer would have expected to be an LLNL activity. The MCCI task seems to have too much focus on DFI in the future plans. If understanding how to co-develop a mixing controlled combustion system with new fuels is wanted, the reviewer suggested starting without something like DFI and fully understanding how the fuels interact with more conventional combustion system design variables, while the DFI is more fundamentally investigated outside of Co-Optima. Subsequently, it can be determined how and why it works and whether it actually could be made in production-robust way.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer commented that an in-depth understanding of fuel spray is crucial for co-optimizing fuels and engines. The project is well-aligned with the goals of Co-Optima program and definitely supports the overall DOE objectives.

Reviewer 2:

The reviewer affirmed that all of these projects support the DOE initiative of reducing energy consumption through various fundamental understanding or new technologies.

Reviewer 3:

The reviewer responded that the project can potentially achieve the DOE goals of Co-Optima.

Reviewer 4:

While the project does support DOE objectives, it also seemed to the reviewer to overlap too much with other DOE VTO funding for the combustion programs, and it does not seem to be pushing in directions that could significantly impact industry ability to make use of the co-optimization idea. The more fundamental spray work is really good for addressing the objectives, but the reviewer stated that the engine-level work just does not look as if it will do much for meeting the objectives.

Reviewer 5:

The reviewer referenced prior comments.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that these projects seem sufficiently funded and any specific differences were commented on in the Technical Progress section.

Reviewer 2:

According to the reviewer, there are sufficient resources to achieve the stated milestones.

Reviewer 3:
The reviewer remarked that the team members have sufficient resources.

Reviewer 4:
At a high level, the reviewer commented that the budget for the project is good. The reviewer would prefer having seen the funding moved more towards the fundamental side for now and later bias it more towards the engine work once the fundamentals are better understood.

Reviewer 5:
Funding seemed sufficient to the reviewer, who was surprised that the presenter did not comment on the significant cut in the funding of his DFI project. The reviewer could not imagine that budget cut did not have an impact on his activities.

Presentation Number: ft057
Presentation Title: Co-Optima—Emissions, Emission Control, and Spray Research
Principal Investigator: Josh Pihl (Oak Ridge National Laboratory)

Presenter
Josh Pihl, Oak Ridge National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

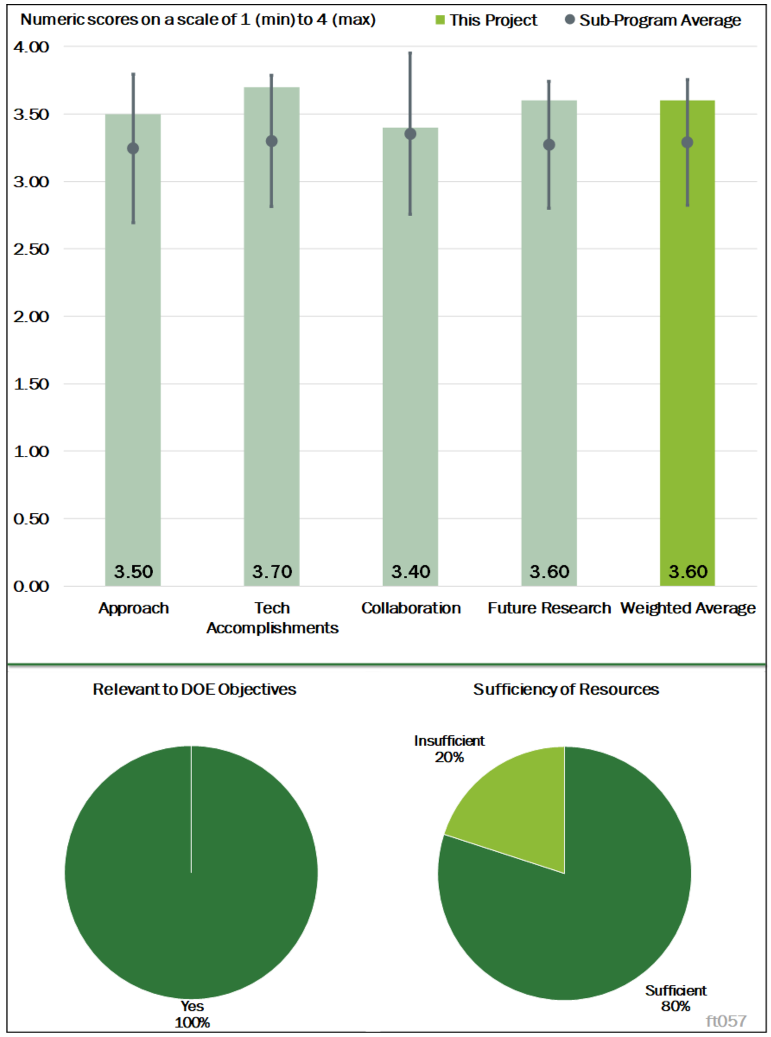

Figure 5-8 - Presentation Number: ft057 Presentation Title: Co-Optima—Emissions, Emission Control, and Spray Research Principal Investigator: Josh Pihl (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer remarked that the project is a good blend of diverse analyses: Cold start/light-off, fuel composition, engine modes, PM and hydrocarbon (HC) considerations, engine variety, and others.

Reviewer 2:
The reviewer commented that the approach to the overall characterization of the impact of fuels on engine performance and emissions is completely in line with the Co-Optima program.

Reviewer 3:
The reviewer said that the project is reasonably designed and planned.

Reviewer 4:
The reviewer pointed out that the approach for the four issues addressed for particulates and gas phase HC species is very developed and being carried out very broadly as this is just a summary of several projects. The role of oxygenates is important to pursue as they appear to be constants for the future in fuels. And in general, one cannot sell a vehicle without meeting the emissions standards for that vehicle, so this research is very critical for looking at new fuel compositions.

Reviewer 5:
The reviewer observed five projects gathered into one presentation, which is difficult to review in its present form. The reviewer stated that the approach is actually gathering a range of ideas and seeing which one hits a button. Nothing in these projects indicates the actual source of soot from various engine combustion technologies. The reviewer commented that the presentation is overflowing with initial speak, which shortens the presentation, but assumes that everyone knows the initial speak. That is not true.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer noted that the project has made excellent progress and appears well on track. Slides 4 and 5 demonstrate the progress while highlighting the remaining steps further backed by the Future Work on Slide 14. Comparing accomplishments to the remaining (future) work, the reviewer noticed the marked project progress.

Reviewer 2:
It seems early in this effort, but the reviewer saw notable results here, especially in the role of fuel alcohols. Excellent work has been done on particulate formation and the effort to see direct emissions impacts of fuel changes is closer.

Reviewer 3:
The proposed tasks in each of the projects have been completed or are being completed.

Reviewer 4:
The reviewer expressed concern about undervaluing the accomplishments of the five different projects crammed into this one presentation. The reviewer thought that the PI did an admirable job of speaking as fast as he could to give the reviewers a snapshot of each of the five elements, but the reviewer thought it is a mistake to try to incorporate this many projects into a single talk.

The only thing that such a setup did was to highlight the strong collaborative nature of the Co-Optima program, which is evident in the way the PI could seamlessly move through the projects. That indicated to the reviewer a high level of familiarity with all of the work, which can only come from regular communication. Kudos to the large team for that.

Reviewer 5:
The reviewer said that it would be a very good idea to develop correlative models to link the yield sooting index (YSI) and PMI to make use of the benefits of both soot indicators. It would also be an excellent idea to expand YSI prediction to the prediction of thermo-physical properties, which are important data needed in the engine spray and combustion computations and optimization.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer saw evidence of excellent collaboration across the national laboratories and commented that it must be an amazing challenge to coordinate teleconferences and meetings. Kudos to the team.

Reviewer 2:
The reviewer stated that collaboration exists; the partners are fairly well coordinated.

Reviewer 3:
It was not clear to the reviewer how tightly integrated the projects actually are; however, much needed information exchange among the partners should actually be happening. The reviewer wished that presentations like this were made available to the "at large" community.

Reviewer 4:
The reviewer found good to excellent collaboration among existing partners at national laboratories and universities. Including catalyst manufacturers is more important at this point in the project. The reviewer mentioned that the 2017 comments addressed this issue, but the evidence for more involvement in this

direction is not clear among the 145 individuals from 86 organizations mentioned as collaborators. A few examples would have been useful outside the national laboratory and university areas.

Reviewer 5:

The reviewer indicated that there is no shortage of collaboration in this project: It integrates several national laboratories, various universities, and other organizations and stakeholders. Not much information, however, was made available on coordination, planning, and execution or allocation of roles and responsibilities. Given such a large mass of investigators across the many organizations involved, the reviewer wondered how effectively coordination and communication are structured. Information in Slide 27 is too basic to clarify such a picture.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

It seemed to the reviewer that there was some cross fertilization among the projects, which the reviewer strongly encouraged. The reviewer believed that the more cross fertilization, the higher likelihood of success.

Reviewer 2:

The reviewer said that the proposed future research is in areas where needs exist that have been identified in the results thus far. The impact of the emissions work with LT catalysts may have the broadest impact.

Reviewer 3:

The reviewer noted that clear and dynamic synergy appears to exist between the progress made to date and the listed future work. Future tasks are targeted at existing challenges or obstacles while they are aligned with the project’s main goals and objectives.

Reviewer 4:

The plan seemed effective to the reviewer.

Reviewer 5:

The reviewer asserted that a complete evaluation of the project was hard because there was so much crammed into this talk. The reviewer thought that it is completely unreasonable to cover five projects in a single talk; they should be separated, even if it extends the AMR. It was impossible to give valuable feedback when the PI zoomed through at a “drug commercial disclaimer” pace.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer indicated that this project clearly is aimed directly at fuel-economy improvements being identified from different fuel blends along with making sure that any results are evaluated from the point of view of the entire vehicle.

Reviewer 2:

Given its consistent focus on the program objective (e.g., PMI, developing predictive capabilities, impact on emissions, etc.), the reviewer noted that the project clearly continues to support DOE funding for this purpose.

Reviewer 3:

Though the reviewer strongly questioned the rational design behind the Co-Optima effort, this project does indeed support DOE objectives.

Reviewer 4:
The project can potentially achieve the DOE goal of Co-Optima.

Reviewer 5:
The reviewer responded that the project probably supports DOE’s objectives and wished that there was convincing information about the active communication among the projects.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer stated that funding is insufficient if it is preventing collaborative work.

Reviewer 2:
The reviewer said that the breadth of research collaborations has provided the level of support that is sufficient.

Reviewer 3:
The reviewer pointed out that 9 DOE national laboratories and 13 universities ae involved; there is no shortage of resources.

Reviewer 4:
The team members have sufficient resources, according to the reviewer.

Reviewer 5:
Resources seemed sufficient to the reviewer.

Presentation Number: ft062
Presentation Title: Characterization of Biomass-Based Fuels and Fuel Blends for Low-Emission, Advanced Compression Ignition Engines (Co-Optima)
Principal Investigator: Ajay Agrawal (University of Alabama)

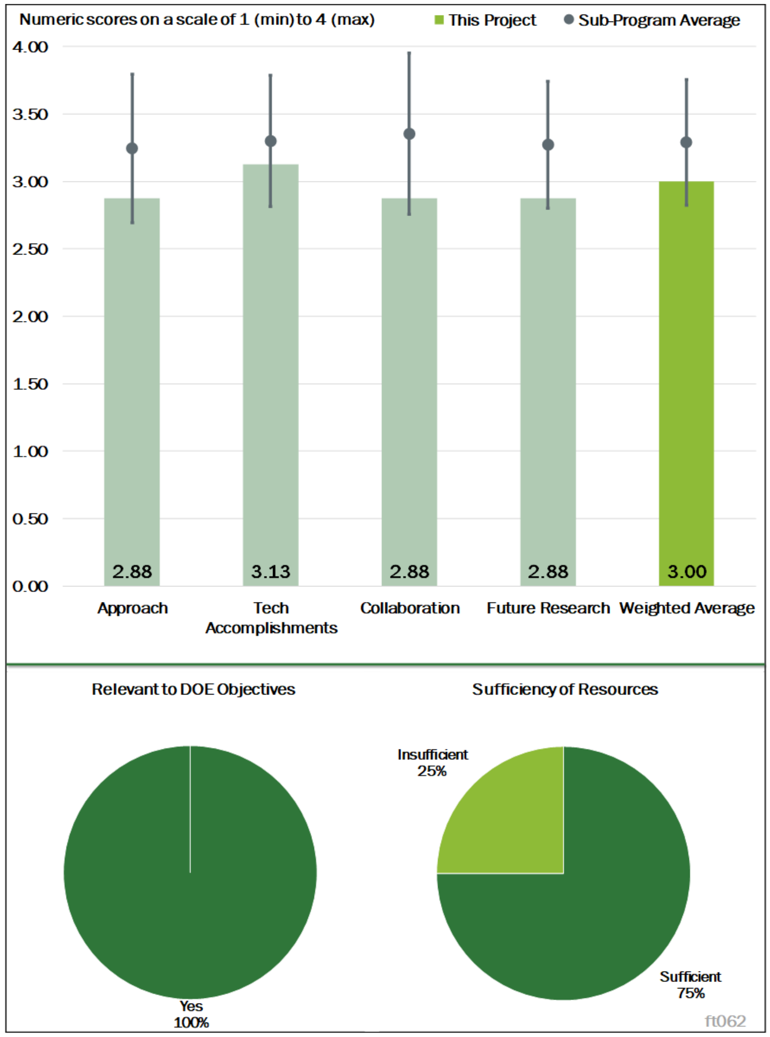

Figure 5-9 - Presentation Number: ft062 Presentation Title: Characterization of Biomass-Based Fuels and Fuel Blends for Low-Emission, Advanced Compression Ignition Engines (Co-Optima) Principal Investigator: Ajay Agrawal (University of Alabama)

Presenter
Ajay Agrawal, University of Alabama

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer remarked that the plan for addressing the technical barriers is sound. In particular, using simultaneous diagnostics, including the innovative rainbow schlieren technique, will provide unique data that will add value to the understanding of fuel sprays. While the current operating conditions are not representative of the entire engine operating range, they are in a relevant range.

Reviewer 2:
For the last year, the reviewer noted that the PI set up the experimental and modeling frame. The combination of several optical diagnostics, advanced statistics, and process modeling is feasible.

Reviewer 3:
The reviewer opined that the rainbow schlieren deflectometry might be able to provide more information, but the reviewer was not sure what additional knowledge it can provide compared to conventional schlieren. The model developed by neural network is a black box. It really does not help better understand the physics of fuel spray and combustion.

Reviewer 4:
The reviewer stated that the approach to this work is okay. The optical diagnostics seem good and understanding how the rainbow schlieren can be applied to combusting sprays will be interesting. According to the reviewer, an area that needs improvement is how the experiments are going to be relevant and linked to Leaner lifted flame combustion (LLFC). The connection between bio-based fuel blends and LLFC was not entirely clear to the reviewer, who suggested that that could be really laid out for better understanding of the

validity of the approach. It seemed to the reviewer that this connection relies on the impact of a bio-based fuel to the supercriticality of the spray. The reviewer wanted to know whether a supercritical fuel spray enables LLFC better. LLFC is mixing controlled, and in the limit, mixing-controlled combustion can be modeled or related to dense gas jets (which are therefore dense fluid mixing and "supercritical"). Additionally, the reviewer said that supercritical states are better achieved with higher pressures and temperatures. The new constant-flow vessel may not be able to achieve relevant pressure and temperatures (+100 bar, +950 K). The approach of the project may produce data and empirical models for irrelevant boundary conditions. The reviewer saw this as a major concern with the new vessel and project approach. An alternative approach may be to take the diagnostics to a different vessel that can achieve the relevant pressures and temperatures.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that the project has made significant progress to date. Establishing the rainbow schlieren technique has been completed and shown to provide insightful data for fuel sprays. Shake-down of the simultaneous diagnostics has provided good baseline data and looks almost ready for implementation in the spray chamber. Based on the original plan, the reviewer said that the program is progressing well.

Reviewer 2:
The reviewer found that preliminary results show that the team is on track to achieving project goals. The rainbow schlieren method produced promising results. The reviewer looked forward to the next year to learning more about quantitative measurements.

Reviewer 3:
The reviewer reported that there has been good progress in setting up the experiments to study fuel spray and combustion.

Reviewer 4:
The reviewer observed that progress on the project seemed to be good. Building a new vessel and setting up optical diagnostics is a fairly good-sized task. The concern the reviewer had is that the success criteria for the vessel and realistic capability may be poorly defined. Again, the reviewer questioned whether relevant temperatures and pressures can be achieved. Industry experience says that getting a flow-through vessel up to +100 bar and +950 K may take significant time and money.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer remarked that the results show good collaboration and coordination with the national laboratory partners.

Reviewer 2:
According to the reviewer, good collaboration has been established with the national laboratories.

Reviewer 3:
The reviewer indicated that the collaboration on this project is satisfactory, mainly because there could be significant leveraging from others working with flow-through vessels and optical diagnostics within Co-Optima. The reviewer urged reaching out to SNL more for their experiences with newly built flow-through vessels and continuing to coordinate with LLNL and ANL on the neural-net modeling.

Reviewer 4:
The reviewer found collaboration with Sandia (Mueller and Pickett) to be a good start, and future coordination with modeling teams at Argonne will be good. In particular, it will be interesting to see if the rainbow

schlieren technique provides unique data for model comparison that other techniques that are currently used by the Engine Combustion Network (ECN) do not. The reviewer encouraged more engagement with simulation teams, as that is a clear plan for how to compare the experimental results and the simulation. Work with the ECN should partially facilitate this, but as the ECN is not focused on fuel blends, other ways of engaging should be considered for the Year 3 work in particular.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer indicated that the planned future work is logical and builds on the preliminary results shown during the presentation. The research team showed awareness of the difficulties ahead for both the experimental and modeling tasks and planned for them.

Reviewer 2:
The future work sounded okay to the reviewer. Being able to evaluate many bio-based fuels in the context of LLFC is good. Alignment to supercriticality, mixing, and LLFC needs further thought. The reviewer urged considering adding decision points about how the project will need to change if relevant pressures and temperatures cannot be achieved in this flow-through vessel.

Reviewer 3:
The reviewer suggested stopping neural-network based modeling, which is trivial using the toolbox in MATLAB. The model is not going to help us better understand the correlations between fuel properties and combustion properties. The reviewer wanted to see more attention paid to understanding the fundamental physics of spray combustion and recommended that the PI develop a methodology to get valuable information out of rainbow schlieren deflectometry.

Reviewer 4:
The reviewer indicated that the future experimental work plan is very strong and the PIs have laid out a clear path for the experiments. The future work with the modeling is slightly less clear to the reviewer; in particular, it was not exactly clear what value the neural-network modeling would add beyond analysis of a given dataset and how it could be used to either gain deeper understanding or advance the state of the art. This is particularly true given that no physics are built into the neural network as it currently stands. The reviewer urged that the PIs should strengthen the neural-network modeling component in future work and identify where this contribution can be unique as compared to other data-analysis and modeling approaches.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented that the project is part of DOE's effort to develop ACI ICEs. The novelty is the combination of three different optical diagnostics is better understanding of fuel-spray characteristics and fuel-composition effects.

Reviewer 2:
The reviewer remarked that the work on this project directly addresses DOE barriers in the areas of advanced combustion and fuel sprays. The Year 3 work will also address barriers related to co-optimization of fuels and engines.

Reviewer 3:
According to the reviewer, understanding spray and combustion of biomass-based fuels and fuel blends is important to co-optimize fuels and engines. It supports the overall DOE objectives.

Reviewer 4:
The reviewer affirmed that this project supports the DOE goals of energy security and increased efficiency with bio-based fuels.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
In the reviewer's opinion, this project is vastly underfunded. Increasing the new flow-through vessel's pressure and temperature capability will take much more money and resources. The reviewer urged considering increasing funding or changing the approach

Reviewer 2:
The reviewer asserted that the PI showed excellent results for the funding received until now. The reason seems to be that the project benefitted from the work previously done by the PIs on the topic and the good facilities at the University of Alabama.

Reviewer 3:
The reviewer stated that there are sufficient resources to achieve the stated milestones.

Reviewer 4:
The reviewer commented that the milestones to date have been met in a timely fashion and the PIs seem to have the required experimental resources to do the proposed work. The issue of a higher pressure facility was raised and the PIs are currently upgrading the facility; however, the resources to go beyond the current plan do not exist. The reviewer remarked that this does not, however, impede the PIs from obtaining new and useful data in the remainder of the project.

Presentation Number: ft063
Presentation Title: Micro-Liter Fuel Characterization and Property Prediction (Co-Optima)
Principal Investigator: Ingmar Schoegl (Louisiana State University)

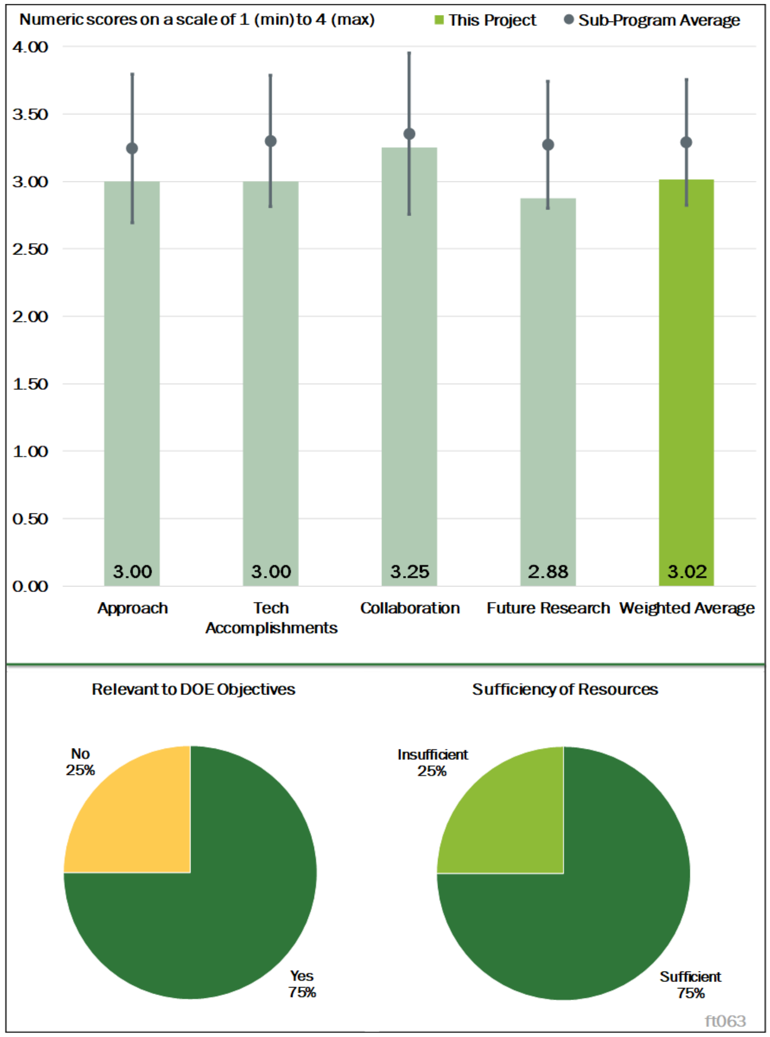

Figure 5-10 - Presentation Number: ft063 Presentation Title: Micro-Liter Fuel Characterization and Property Prediction (Co-Optima) Principal Investigator: Ingmar Schoegl (Louisiana State University)

Presenter

Ingmar Schoegl, Louisiana State University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

With regard to screening fuels reasonably quickly and with consistency, the reviewer remarked that the micro-flow reactor appears advantageous as it enables measurement access. The team members and collaborators are quite strong.

Reviewer 2:

If it can be successfully developed, the reviewer stated that this will be an important capability for Co-Optima. The researchers' approach to achieving this goal is well laid-out and is correctly focused on the most important conditions for which engine-relevant data are needed.

Reviewer 3:

The reviewer said that the project is using an innovative approach based on a micro-flow reactor to enable fuel characterization using micro-liter quantities. If successful, the technique would facilitate characterization of fuel components in early stages of development when only small quantities are available. Additionally, the reviewer suggested that the technique has the potential to enable automated testing for multiple samples, thereby allowing a high throughput.

As described, the reviewer opined that the technique should be able to generate data on laminar flame speed and impact of dilution (air/EGR) on combustion. However, it was not yet evident to the reviewer how ignition delay, RON, MON, and sensitivity will be determined. It was also unclear to the reviewer how any ignition-delay measurements made using this technique will be compared to ignition-delay measurements from RCMs and shock tubes.

Key technical barriers have been identified and are being actively pursued, which is critical for success. The reviewer expected that next year's update will provide a clearer picture of the capabilities and limitations of the proposed technique (e.g., low and high vapor-pressure fuels). While there are uncertainties and multiple technical barriers, the reviewer remarked that the proposed technique shows a lot of promise.

Reviewer 4:

The reviewer remarked that this is an untested procedure and the chances of success seem just fair. The small size of the reactor maximizes contributions from surface reactions, which may lead to faster or slower burn rates than what actually occurs in engines. According to the reviewer, a key parameter is the surface-to-volume ratio. An appropriate test procedure should be carried out with different configurations for reactors.

The reviewer noticed another issue to be evaluated is to control the size of the droplets because the liquid has to evaporate completely before burning. Different droplet sizes should be experimentally tested. The reviewer inquired about how long complete burning takes under any given set of conditions (tube diameter, droplet size, temperature, pressure).

According to the reviewer, experimental conditions need to be clarified and specified, especially temperature and pressure, with the smallest possible uncertainty. These uncertainties have to be understood and quantified because they will be propagated during the simulation phase. Otherwise, the reviewer suspected that it will be challenging to make decisions based on the data that will be derived from these experiments. The 3-year period might not be long enough to develop a reliable and standardized methodology.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

While the project has only completed its first year, the reviewer summarized the good progress made in development of the proposed technique: apparatus modifications and upgrades to enable testing at 10 bar with work underway to extend the capability to 30 bar; implementation of thin-filament pyrometry to enable temperature measurements along the length of the tube; preliminary results from experiments investigating the impact of flow velocity, equivalence ratio, pressure, and fuel composition; and the successful demonstration of nanoliter fuel delivery. The project is making good progress and is currently on track.

Reviewer 2:

The reviewer observed good progress for a project underway for little over a year: a number of key improvements to the experiment system have been made; pressure effects have been determined; and data generation on reference fuels has progressed

Reviewer 3:

The reviewer said that the program is just completing its first year. The progress is good and is encouraging. There is a long way to go, but at this time, success appears likely.

Reviewer 4:

The reviewer pointed out that on Slide 5 on the presentation, the milestone M1.2 should be covering the limits of pressure and temperature (range of pressures including lower and upper limits) at which combustion occurs inside the micro-reactor. At some point, the success and failure of this micro-reactor has to be fully understood when it comes to operating conditions. Milestone M1.2 seemed incomplete for the former reason to the reviewer. Consequently, the reviewer suggested that M1.4 should be re-explored for a set of test results that really cover the relevant metrics because these metrics have not been truly examined and specified.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the project is demonstrating progress because of its collaborative efforts.

Reviewer 2:

The reviewer saw the project as a highly collaborative part of the Co-Optima team.

Reviewer 3:

The reviewer commented that the PI is working closely with national laboratory collaborators as well as sub-contractors.

Reviewer 4:

The reviewer indicated that the team should have access to databases that cover engine testing and performance. The level of collaboration needs to be expanded, for example, to include work from the American Society of Testing Materials and the American Petroleum Institute.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer pointed out that the principal focus of future work is to develop the capability to operate the measurement system at engine-relevant temperatures and pressures. The reviewer agreed that this is the most important objective to pursue.

Reviewer 2:

According to the reviewer, the proposed research is in line with the goals of the project and aimed at addressing the technical barriers that have been identified.

Reviewer 3:

The reviewer noted that the research plan is okay but it would appear to need to move more quickly to have significant impact and relevance in the overall Co-Optima fuel assessment.

Reviewer 4:

The reviewer stated that the technical needs to make this project successful are underestimated. Ignition delay measurements from Texas A&M University were referenced out of nowhere on Slide 21 of the presentation, which prompted this reviewer to ask how these measurements overlap with the current micro-reactor program. The relationship between ignition delay and the rate constants is significantly more complex. This reviewer further requested that chemical reactions are properly written (i.e., $A+B \rightarrow C+D$). Initial qualitative results are uncertain and need estimates for error limits, according to this reviewer, who emphasized the need for effective experimental parameters and instrumentation design.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

For effective assessment of potential new fuels or fuel components, the reviewer said that it will be important to be able to determine their engine relevant characteristics: RON and sensitivity, for example. If successfully developed, the reviewer stated that this system would allow such measurements to be made for very small test samples of candidate fuels.

Reviewer 2:

At the current stage of the study, the reviewer commented that the results are very preliminary and have not been compared with other analogous measurements and procedures for validation purposes. On the other hand, the reviewer exclaimed that the idea of utilizing micro-liter reactors for fuel testing has interesting possibilities.

Reviewer 3:

The reviewer noted that the development of micro-liter fuel characterization is not only relevant to Co-Optima but for fuel studies in general.

Reviewer 4:

The reviewer commented that a couple of years ago, a high-throughput, small-sample assessment method appeared important and potentially useful in contrast to other types of fuel-screening combustion vessels. The number of fuel permutations does not seem all that many at this time. Other methods, including detailed chemical and structure analysis, may give more informative results on performance and emissions tendencies. The reviewer indicated that the best screening method for engines is to use the engine.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

According to the reviewer, experience shows that the development of a new standardized procedure will require much larger resources that those initially anticipated.

Reviewer 2:

The reviewer reported that there are numerous contributors and advisors to the core team. This helps with the overall resource needs.

Reviewer 3:

The reviewer mentioned that resources appear to be sufficient for the proposed scope of the project.

Reviewer 4:

It appeared to the reviewer that the program has sufficient funding.

Presentation Number: ft064
Presentation Title: The Development of Yield-Based Sooting Tendency Measurements and Modeling to Enable Advanced Combustion Fuels (Co-Optima)
Principal Investigator: Charles McEnally (Yale University)

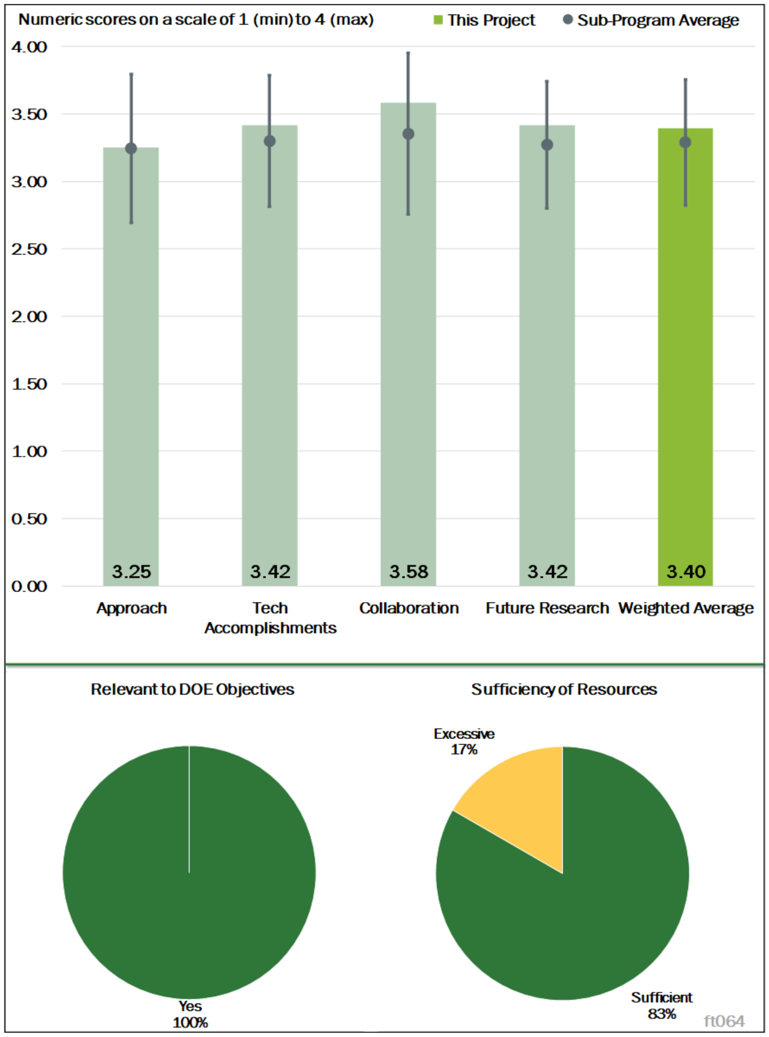

Figure 5-11 - Presentation Number: ft064 Presentation Title: The Development of Yield-Based Sooting Tendency Measurements and Modeling to Enable Advanced Combustion Fuels (Co-Optima) Principal Investigator: Charles McEnally (Yale University)

Presenter
Charles McEnally, Yale University

Reviewer Sample Size
A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer commented that the approach to do the two-dimensional simulation appears very appropriate and, with the interaction from other laboratories and universities, leads to useful results for other laboratories to use in their Co-Optima work. Providing a source of understanding to a range of people using these results is an excellent way to begin this work. The reviewer noted that having a database of over 400 compounds available is itself a major initial effort that is very beneficial to include.

Reviewer 2:
The reviewer remarked that the investigators used a first-principles approach, a blend of know-how from authentic published literature, expertise from national laboratories, experimentalists and computationalists, and fundamentals of diffusion-flame and fuel chemistry. The speaker also did an excellent job presenting the work and answering all of the questions with well-rounded answers.

Reviewer 3:
The reviewer opined that YSI is likely going to be a more precise metric for screening fuels. The two main advantages are the ease of measurement and the low volumes required. Two things the reviewer perceived were missing from the approach was a strategy to deal with fuels beyond the “bookends” of n-heptane and toluene, and no discussion of blend effects. For example, the reviewer wanted to know what happens to YSI of a 50:50 blend of toluene:n-heptane. The reviewer asked if it is dominated by the high YSI component. There needs to be more investigation of the blend effects and core Co-Optima fuels, according to the reviewer.

Reviewer 4:

For the experimental YSI approach, the reviewer referenced a great question raised by one of the reviewers, which inquired about using hydrogen (H_2) in a nitrogen gas (N_2) fuel for the flame so that all carbon would be from the doped fuel?" The reviewed commented that there was not a satisfactory answer given (lack of time, perhaps) and that it would have been nice to see this addressed. Additionally, the reviewer wanted to know why the values for equations 1 and 2 (Slide 7) are defined as such. The reviewer said the approach YSI simulations seem to be well done, and opined that considering the number of components in standard pump gasoline and diesel fuels, calling 400 compounds a "comprehensive" database (Slide 9) is a bit much.

Reviewer 5:

The reviewed stated that the approach of the project is highly fundamental for application to engine work. It was unclear to the reviewer how the YSI evaluation for atmospheric-pressure laminar flames will be applicable to engine conditions that are highly turbulent and are at high pressures. Granted, the study is looking to understand fuel effects on soot formation; however, different ambient conditions give rise to different sooting tendencies for the same fuel. It was unclear to the reviewer if the percentage of monoaromatic and the percentage of polyaromatic HCs in fuel are considered in the machine-learning model for soot predictions. Also, when transitioning to LTC conditions, the reviewer inquired if YSI is a good indicator for PM as at LTC conditions, PM has low content of soot and high content of HCs.

Reviewer 6:

After fighting through FT057, it was nice for this reviewer to have the detail on one of the projects. The reviewer warned that creating a YSI library is a wise, but a boring way to do the research. This library will carry this information forward and impact many other projects in the future.

However, over the years of Glassman and his students evaluating the behavior of lifted burn flames and their properties, the reviewer was disappointed not to see a more detailed description of the flame structure and what property, if there is one, gives the soot measurements reproducibility. The description of the modeling effort of the flames is encouraging; however, there are extraneous influences that change the results. The reviewer would like to have seen an uncertainty for the measurements.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found that good progress has been made on all of the milestones that are appropriate for this project. There is an ambitious timeline and the project team appears to be meeting it.

Reviewer 2:

The reviewer noted that the project started recently (May 2017) and technical progress is on track. The team has established the base methane flame and has validated the soot model for the base flame. It was unclear to the reviewer what soot model is being used and what inception and surface growth species are being used in the model.

Reviewer 3:

The reviewer stated that having a database of YSIs covering a range of two orders of magnitude for a various fuels, as well as studying the new molecular fuels is a good start. For these early stages, the team has completed an impressive number of relevant and useful results, especially highlighted by the oxygenated aromatics work. The reviewer offered that comparison with experiments in more realistic settings, of course, is yet to come.

Reviewer 4:

The reviewer commented that Slides 11-12 are a great indication that there are simplifying concepts that can simplify the soot formation for this flame. The creation of a sooting reaction mechanism is a great way to impact research chronologically down the line.

The reviewer especially appreciated the publication of a comprehensive list of the sooting yields of a range of compounds. The reviewer pronounced the modeling to be very encouraging yet wondered if the reaction mechanism(s) is/are available somewhere. The reviewer asked why a flamelet-based model is needed for a flame that should have stability.

Reviewer 5:

While the investigators had a noticeable focus on the objectives, the reviewer said that the work is said to target applications to engine combustion as clearly stated in the presentation title, "…to enable advanced combustion fuels." It would have been helpful to the reviewer if the work/presentation included, at a minimum, highlights on how such transition would be made: From focus on the fundamentals (which the investigators did an excellent work on) to applications in real-life (engine combustion), including impact of in-cylinder combustion and boundary conditions (geometry, air-fuel mixing mechanisms, turbulent effects, etc.). The reviewer indicated that this need not have been a detailed analysis, but painting the pathway for such real-world applications.

Reviewer 6:

The reviewer stated that there was a very interesting result on the dependence of oxygen-bond type/species on the YSI measured. There were very nice modeling results of the methane-flame soot formation. The reviewer's main concern was not really seeing how any of these results relate to combustion in an engine. The reviewer also did not see any plan for relating these results to actual engine results.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that Yale University and Pennsylvania State University are working closely with key national laboratory and other academic participants in Co-Optima. There are very strong collaborations throughout.

Reviewer 2:

The reviewer reported that the team has not shied away from utilizing any available expertise or information (published or available otherwise, such as the Harvard Dataverse, or within national laboratories) to broaden their understanding of the mechanisms involved or to build their know-how.

Reviewer 3:

If the DOE paid for this work, the reviewer urged that at least a link to https://doi.org/10.7910/DVN/7HGFT8 should be included on the Crosscut Lean Exhaust Emissions Reduction Simulations website. The reviewer opined that the entire "at large community" is a stakeholder in this project. The reviewer found the collaboration group to be of very high quality.

Reviewer 4:

The reviewer said that collaboration with Co-Optima appears evident from the description. The publications do not yet reflect that, if that is appropriate at this point. At these early stages, Yale and Penn State are performing the work, but the team should find results from a broader base of researchers as time goes on.

Reviewer 5:

The reviewer noticed that Slide 14 identified the wrong laboratory partner. ORNL is not a listed collaborator and NREL is called out later in the slide. Again, the reviewer would like to see some engine-relevant collaboration, with perhaps ORNL.

Reviewer 6:

The reviewer commented that there is good national laboratory collaboration in the project but no industry collaboration. This project is at a very low TRL where industry may not see value, which concerned the reviewer. Having said that, the reviewer acknowledged that the work is very important in understanding the science behind soot formation for various fuels and hence it is important that the lessons from this study are applicable to engines, which is not clear at this point.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

According to the reviewer, the proposed future research is in line with work thus far and new results from other laboratories. The reviewer stated that including fuels for MCCI is important, as is also developing better simulations of YSIs.

Reviewer 2:

The reviewer remarked that all three key areas of future work as stated in the presentation are well within the targeted objectives. Painting pathways to in-cylinder applications would be helpful and within the project's end-charter.

Reviewer 3:

The reviewer stressed the need to relate this project to engine operation.

Reviewer 4:

The reviewer asserted that developing a YSI table for compression-ignition engines is a must-do for this project to have the impact it should have.

Reviewer 5:

The reviewer pointed out that the project is only 30% complete so the proposed future work remains on target and appropriate for the objectives of the project. There is keen interest in how the YSI will relate to sooting behavior in a real engine. Although there is not work planned in GDI, there exists a great deal for information within Co-Optima both at steady state and transients for the sooting behavior of GDI engines with Co-Optima blends. The reviewer commented that it would be very interesting to know what the YSI of the Co-Optima core gasoline fuels are and how that relates to observed GDI soot behavior; that would take a relatively short time to do. In addition, NREL has engine soot data on several simpler blends that could be correlated with YSI.

Reviewer 6:

The reviewer said that evaluating sooting tendencies at atmospheric pressures with laminar flames may not be directly applicable to soot formation in engine conditions. If the reviewer had to give one suggestion, then it would be to perform the experiments at elevated pressures. (20 atmospheres [atm] or 40 atm). At least the effects of pressure on the flame and soot formation/oxidation mechanisms would be captured to some extent. The effect of turbulence is hard to capture in flames.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer exclaimed that a sooting index that is appropriate for a range of ICEs and a range of fuels would be wonderful.

Reviewer 2:
Co-Optima projects are defined to support DOE objectives by lowering the cost and enhancing reliability of fuel usage and the meeting of emissions-control standards, according to the reviewer.

Reviewer 3:
The reviewer said that this project, focused on "...enabling advanced combustion fuels," meets the DOE goal of optimizing fuel-engine sub-systems for Co-Optima.

Reviewer 4:
The reviewer agreed that this project meets all of the criteria for being relevant both in the area of fuel screening and emissions assessment for new Co-Optima blends.

Reviewer 5:
The reviewer affirmed that this project seems to achieve the objectives of Co-Optima and the Co-Optima university funding opportunity announcement.

Reviewer 6:
The reviewer acknowledged that the project meshes well with the Co-Optima program of DOE and addresses the overall objectives of DOE.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented that the team has done a good job filling in the project needs via reaching across to external resources (e.g., national laboratories) and to integrate various needs (expertise, data, etc.) into the project. The reviewer noticed no shortage of resources or observed excess resources.

Reviewer 2:
The reviewer indicated that resources, especially with this array of potential collaborators, seem sufficient. No issues are raised about work at Yale and Penn State, except to assure that funding continues.

Reviewer 3:
According to the reviewer, funding so far has certainly provided encouraging results.

Reviewer 4:
The reviewer said that the project just completed 1 year and the resources seem to be sufficient for the successful completion of the project.

Reviewer 5:
The reviewer found the budget to be appropriate for the work scope.

Reviewer 6:
The reviewer suggested that the budget seems rather high for this work.

Presentation Number: ft065
Presentation Title: Dynamic Species Reduction for Multi-Cycle Computational Fluid Dynamics (CFD) Simulations (Co-Optima)
Principal Investigator: George Lavoie (University of Michigan)

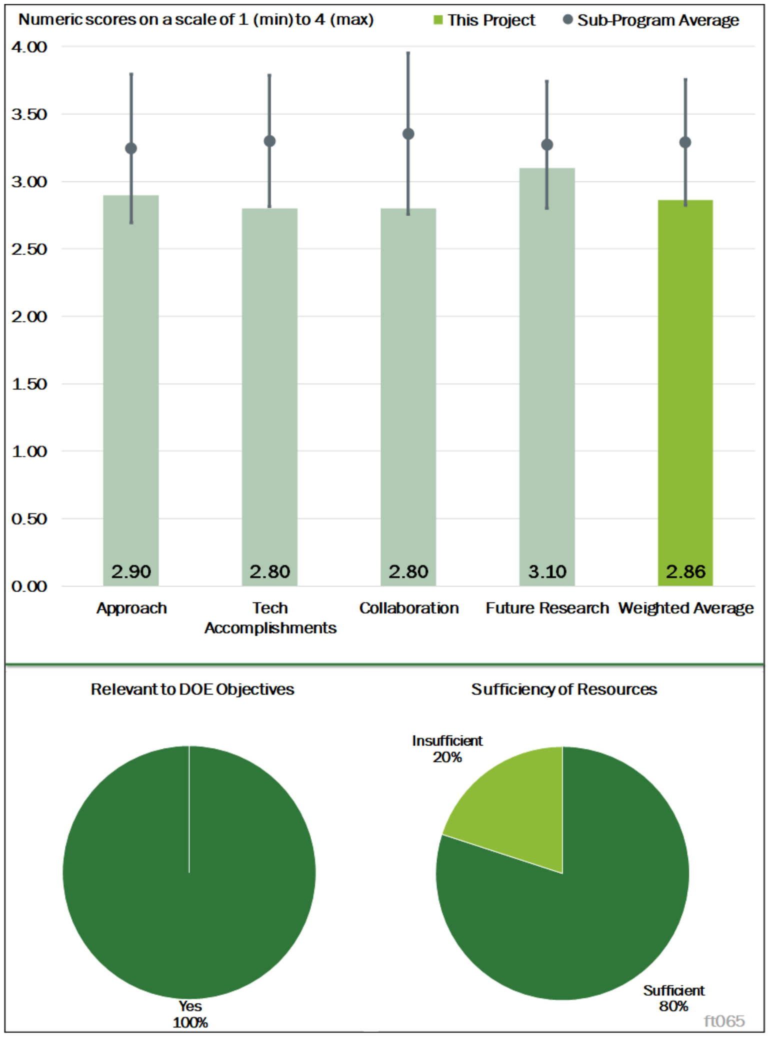

Figure 5-12 - Presentation Number: ft065 Presentation Title: Dynamic Species Reduction for Multi-Cycle Computational Fluid Dynamics (CFD) Simulations (Co-Optima) Principal Investigator: George Lavoie (University of Michigan)

Presenter
Rob Middleton, University of Michigan

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The approach was reasonable to the reviewer

Reviewer 2:
The reviewer said that the success of this work depends on the use of the proper chemical kinetics database.

Reviewer 3:
The reviewer stated that the concept of the project is good. The investigators seem to be convincing in their arguments that “little” chemistry occurs during the non-valve overlap region. In general, the reviewer would agree with that conclusion, with the caveat that very slow chemistry occurs and probably has very small impact on the overall combustion kinetic description. The reviewer proclaimed that the skip-species option in CONVERGE clearly misses appreciable chemistry. It changes combustion character. There is no clear reason given why the University of Michigan dynamic species reduction (DSR) approach “fixes” the problem. A common problem with dynamic species reduction is that the re-emergence of a species in a future step has no history; there are n. o derivatives in terms of growth and second-order behavior. The reviewer wanted evidence that the combustion process did not “wander” over longer times due to the approximations.

Reviewer 4:
The reviewer remarked that this project presents a very important part that is missing in other Co-Optima projects because it looks into modeling multi-cycle simulations that will be essential for transient control and mode switching. The approach for dynamic species reduction is well-planned, building upon prior experience. Converting the codes from KIVA to CONVERGE is fine. The reviewer stated that that the major missing part is not having a detailed multi-cycle experimental validation beyond an in-cylinder pressure trace, which is not difficult to achieve. Validating other combustion metrics like cycle-to-cycle heat release and engine-out

emissions should be considered, assuming these data can become available to the PI from the ANL group. This reviewer agreed that if the selection of the ACI mode takes too long, the PI can start with prior HCCI data at the University of Michigan through previously funded DOE projects. So, the project can do proper, full-cycle, multi-cycle evaluations.

Reviewer 5:

According to the reviewer, the overall project objectives are clear. The high-level approach and the tasks are also stated reasonably well. However, there is a lack of in-depth technical descriptions on the fundamentals of the DSR/re-mapping techniques employed in this project and in which areas they offer improvements over the dynamic mechanism reduction and multi-zone modeling approaches that are currently built in CONVERGE. Also, the reviewer indicated that the target size and components of the base detailed/semi-detailed kinetic mechanism need to be well defined such that the project benefit and impact can be properly evaluated.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Considering the personnel change, the project has made reasonable progress on acquiring engine meshes, attaining baseline simulation results, and implementing the University of Michigan DSR routines into CONVERGE.

Reviewer 2:

The progress seemed reasonable to the reviewer.

Reviewer 3:

The reviewer found not much progress at this stage of the project.

Reviewer 4:

The reviewer pointed out that the work seems to be subject to program management delays.

Reviewer 5:

The reviewer commented that the project presents interesting results for the significance of considering species reaction during negative valve overlap. In addition, the findings for not needing to consider species reaction during gas exchange from exhaust valve opening to intake valve closure and during open valve is of great value for the research community. The project will not be able to fulfill the goal of 80% computation time reduction in CONVERGE with DSR.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer described the collaboration as a supplier collaboration, i.e., Convergent Sciences gets DOE/University of Michigan (UM) to develop a submodel for nothing. The reviewer asked what the give back is to UM, who gets license fees, and who gets public credit; this is a common problem. Having been in similar negotiations, this reviewer did not want UM and the students mined for free. Unfortunately, UM is in the submissive position. Strongly emphasizing that only licenses are not enough, the reviewer suggested marketing it as the Convergent Sciences/UM version of the code.

Reviewer 2:

The collaboration seemed reasonable to the reviewer.

Reviewer 3:

The reviewer suggested that the authors take into consideration the work done on sensitivity analysis by Dr. Hai Wang from Stanford University for one-dimensional homogeneous systems.

Reviewer 4:

The reviewer pointed out that the project includes collaborations among the University of Michigan, ANL, and Convergent Science. The collaboration with other Co-Optima members needs to be increased because other Co-Optima projects are lacking the parts that are studied in this project. Further collaboration provides avenues to receive further experimental data required for multi-cycle experimental data validation. This also creates opportunities to see the effect of the project outcomes on different ACI combustion regimes.

Reviewer 5:

The reviewer noted that the project overall has good collaborations with ANL and Convergent Science. To better support the Co-Optima goals, establishing good coordination and collaboration among this project, the ANL CFD team, and the Co-Optima kinetics/simulation toolkit team would be beneficial.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that the future work is well planned to address the remaining technical challenges and barriers.

Reviewer 2:

The reviewer stated that the future work includes logical next steps towards the goals of this project.

Reviewer 3:

The next steps looked appropriate to the reviewer.

Reviewer 4:

The reviewer found the future work to be reasonable.

Reviewer 5:

The reviewer looked forward to seeing the success and completion of this first stage before considering the quality of the results.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer stated that the project is making progress towards the goal of developing a modeling tool to study cycle-to-cycle variability that can lead to robust, fuel-efficient ICEs that are commonly used in vehicles. This supports the goal of the Co-Optima program to reduce vehicular fuel consumption by 10% for LD vehicles.

Reviewer 2:

By accelerating the computation time for multi-cycle, 3-D, CFD engine simulation, the reviewer indicated that this project provides good support towards achieving the Co-Optima goals and the overall DOE objectives.

Reviewer 3:

The reviewer remarked that the work is very much relevant to DOE objectives because it is coupling fluid dynamics with chemistry.

Reviewer 4:

The reviewer found the work to be reasonable.

Reviewer 5:

The reviewer commented that faster is better.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the resources are adequate to achieve the project milestones and address the technical barriers.

Reviewer 2:
The reviewer indicated that the outline of the project is aligned with funding.

Reviewer 3:
The reviewer noted that resources are reasonable.

Reviewer 4:
The reviewer reported that resources seem to be sufficient. Money from Convergence would move the project along better.

Reviewer 5:
The reviewer suggested that the PI needs to recruit/find graduate student(s) in order to achieve the project goals on time. Computational resources are sufficient for this project.

Presentation Number: ft066
Presentation Title: Reduced Petroleum Use through Easily Reformed Fuels and Dedicated Exhaust Gas Recirculation
Principal Investigator: Tom Briggs (Southwest Research Institute)

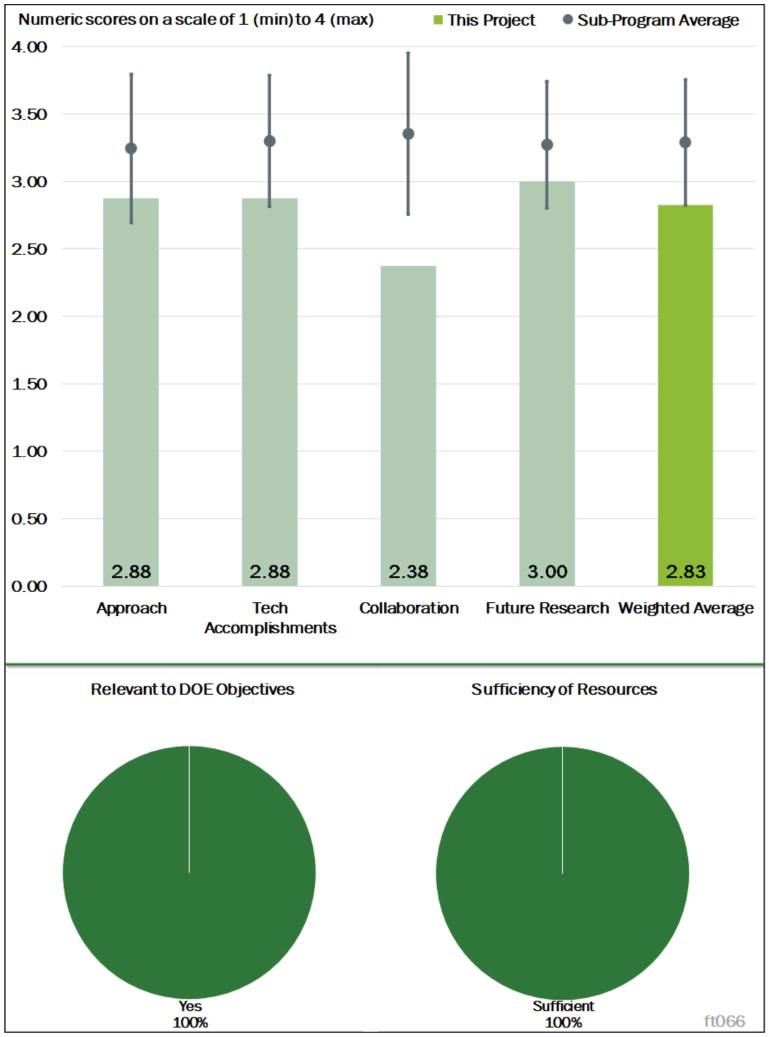

Figure 5-13 - Presentation Number: ft066 Presentation Title: Reduced Petroleum Use through Easily Reformed Fuels and Dedicated Exhaust Gas Recirculation Principal Investigator: Tom Briggs (Southwest Research Institute)

Presenter
Tom Briggs, Southwest Research Institute

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
With respect to investigating fuel effects to enhance the H_2 production and dedicated EGR technology, the reviewer stated that the approach being taken is very solid. The project appears highly dependent on experiment results. A stronger modeling component would be advantageous, according to the reviewer.

Reviewer 2:
The reviewer noted that dedicated EGR has the potential to improve ICE efficiency. Understanding the fuel effect on H_2 production and the approaches of further improving dedicated exhaust gas recirculation (DEGR) efficiency is valuable. The reviewer suggested that the project can be improved by adding CFD modeling.

Reviewer 3:
The reviewer remarked that the approach is a compelling way to extend the lean/dilution limit and combustion stability of engines. The goal of operating a stoichiometric gasoline engine is also compelling as it eliminates the need for a complicated aftertreatment system.

According to the reviewer, the project team has studied internal EGR reformation for a number of years and has produced great results. An unanswered question is the commercial feasibility of a dedicated EGR system. Extending the lean limit even further requires additional H_2 production and requires running the dedicated cylinder even richer (absent a better H_2 producing fuel). The reviewer said that this will lead to higher HC and soot emissions, which will lead to EGR-cooler fouling. The presenter suggested that at a phi of 1.3, the EGR cooler did not foul; however, H_2 production was around 3%. At a H_2 generation of 8% and a phi of 1.6, the presenter suggested the EGR cooler fouled and plugged. These results suggested to the reviewer that there is a limit to how much H_2 is feasibly generated and the extent to how far the lean limit can be extended.

Beyond an improvement in the hydrogen-to-carbon (H:C) ratio in the fuel, it was unclear to the reviewer how a fuel can be biased to produce additional H_2 without looking at the kinetic pathways. The reviewer commented that this does not appear to be in the project scope. The reviewer observed that this project is very similar to Co-Optima, with the creation of a special fuel that can bias H_2 production and designing an engine that can take advantage of it (higher CR mainly). It was unclear to the reviewer why this project is a standalone and not part of the Co-Optima program.

Reviewer 4:

The reviewer remarked that this project improves the potential of DEGR. The goal is to find a new chemistry via new fuel options to generate more H_2 in the dedicated cylinder, for example, via an increased H:C ratio. The reviewer wanted to know whether this exploratory work of finding new chemistry with a new fuel could be done via simulation first to filter out several options and guide the experiments. According to the reviewer, DEGR itself has found challenges on its path to production implementation with current market fuel. The reviewer inquired if it is prudent to think that adding the complexity of a new fuel will help that situation.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the investigations of how to increase H_2 production via injection controls and valve timing produced important results. Confirming key features of fuels for H_2 generation was an important finding.

Reviewer 2:

The reviewer found the project to be on track to achieve its objectives.

Reviewer 3:

The reviewer indicated that progress has been very slow, with paperwork being blamed.

Reviewer 4:

The reviewer posited that the work using H_2 enrichment is extremely compelling. The ability to shorten combustion duration with H_2 enrichment can extend the load limit of high-dilution engines and also lead to higher CR engines by mitigating knock. According to the reviewer, the results presented showed a H_2 generation of almost 8%, however, at the cost of EGR-cooler fouling. A 3%-enrichment was theorized to increase the CR by 1-2 points, which would ideally increase the ideal cycle efficiency by a similar number of points. It was unclear to the reviewer how much of the efficiency advantage gained by H_2 enrichment in the main cylinders is negated by rich operating conditions in the dedicated cylinder. The HC, CO, and H_2 would be oxidized in the engine so overall combustion efficiency is still high (minus what condenses out in the EGR cooler). The reviewer requested information on overall engine efficiency as well as per-cylinder efficiencies in future presentations. Additionally, the reviewer said that the durability of the additional hardware responsible for circulating the DEGR is not addressed. The goal of increasing the CR with H_2 enrichment would decrease ignition delay and stretch out burn rates. The effect of this on overall efficiency and minimum enrichment levels to avoid knock was not clear to the reviewer.

The reviewer commented that the ability to modulate injection strategy to extend robust combustion in the dedicated cylinder is a good idea; however, no coefficient of variation (COV) of IMEP values was presented. For future presentation, the reviewer requested information on COV of IMEP.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
According to the reviewer, there is collaboration with Fiat Chrysler Automobiles (FCA) and an energy company. It could be ideal to link this project to Co-Optima program.

Reviewer 2:
The reviewer stated that the technical engagement by Total and FCA does not appear very strong. Eventually, this project should be more engaged with the fuel strategies in Co-Optima. The reviewer wanted to know how this effort is leveraged or independent of the High-Efficiency Dilute Gasoline Engine (HEDGE) program.

Reviewer 3:
The reviewer said that the project incurred a significant delay, and as such, there does not appear to be significant interaction among the partners. There is future work identified to procure a higher CR engine from one of the partners; however, the future plans are vague for the fuel supplier.

Reviewer 4:
The reviewer stressed that it is very critical that either a petroleum or biofuel-based fuel supplier be part of this project, not just to supply test fuels but to collaborate at a higher level to guide it in selecting fuel options that have viable commercial pathways.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer stated that the right areas have been identified for the remaining work.

Reviewer 2:
According to the reviewer, the project is planned in a logical manner and there is no major risk. The reviewer encouraged the PI to put more effort into understanding the fundamentals of fuel impacts on H_2 production and DEGR combustion.

Reviewer 3:
The reviewer remarked that the future work would appear stronger if the relationship to the Co-Optima fuels matrix were made clearer. Co-Optima does not seem to have a fuel path for DEGR-type engines.

Reviewer 4:
The reviewer pointed out that this project incurred a significant pause which likely affected the current status and future work of the project. The future work identified is basic in nature, but a higher CR engine to utilize the H_2 enrichment is important to understand the efficiency benefits of the engine. Tailoring a fuel with a higher H:C ratio will also help H_2 production; however, biasing the production of H_2 in the DEGR cylinder requires kinetic modeling, which the reviewer recommended. Achieving a richer than 1.3 phi in a durable configuration (i.e., EGR-cooler fouling) will be challenging and thus additional insights in the reformation process are required. The reviewer suggested this as future work.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
According to the reviewer, DEGR is a novel ICE technology, potentially achieving better engine efficiency. It is worth studying the fuel impact on DEGR combustion.

Reviewer 2:

The reviewer said that this project aims to increase engine efficiency and hence petroleum-use reduction.

Reviewer 3:

The reviewer remarked that DEGR-type technology is a fundamentally, directionally sound path to higher engine efficiency. It is one of the more innovative approaches though not simple to implement.

Reviewer 4:

The reviewer indicated that this work strongly supports DOE's vision of energy security, higher efficiency engines, lower emissions engines, and lower cost technologies. The reviewer questioned whether it should be a standalone project or if it should be incorporated into the Co-Optima program as the objectives are similar.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer indicated that there are sufficient resources to achieve the stated milestones.

Reviewer 2:

The reviewer observed that Initial exploratory work can be done with the provided resources.

Reviewer 3:

The reviewer stated that the budget is appropriate for the project scope and goals. Kinetic modeling may require a slight increase in the budget, but should be manageable.

Reviewer 4:

The reviewer found the resources to be at least sufficient. Companion work under the HEDGE consortium is significant. A few words about the interface are needed in the presentation.

Acronyms and Abbreviations

3-D	Three-dimension
ACI	Advanced compression ignition
ACI-F	Advanced compression ignition: fuel effects
AFIDA	Advanced fuel ignition delay analyzer
AMR	Annual Merit Review
ANL	Argonne National Laboratory
atm	Atmosphere
BAU	Business as usual
CFD	Computational fluid dynamics
CFR	Constant-pressure flow rig
CO	Carbon monoxide
COV	Coefficient of variation
CR	Compression ratio
CRADA	Cooperative research and development agreements
DEGR	Dedicated exhaust gas recirculation
DFI	Ducted fuel injection
DOE	U.S. Department of Energy
DSR	Dynamic species reduction
dT	Change in temperature
ECN	Engine Combustion Network
EGR	Exhaust-gas recirculation
FCA	Fiat Chrysler Automobiles
FE	Fuel economy
FT	Fuel and Lubricant Technologies
FY	Fiscal Year
GCI	Gasoline compression ignition
GDI	Gasoline direct injection

H_2	Hydrogen gas
HC	Hydrocarbon
HDV	Heavy-duty vehicle
HCCI	Homogeneous-charge compression ignition
HD	Heavy-duty
HEDGE	High-Efficiency Dilute Gasoline Engine
HOV	Heat of vaporization
ICE	Internal combustion engine
IMEP	Indicated mean effective pressure
KC	Kinetically controlled
LD	Light-duty
LLFC	Leaner lifted flame combustion
LLNL	Lawrence Livermore National Laboratory
LT	Low temperature
LTC	Low-temperature combustion
MCCI	Mixed-mode compression ignition
MD	Medium-duty
ml	Milliliter
MON	Motor octane number
MS	Mass spectroscopy
NA	Naturally aspirated
NO_x	Oxides of nitrogen
OEM	Original equipment manufacturer
OS	Octane sensitivity
PAH	Polycyclic aromatic hydrocarbon
PI	Principal Investigator
PM	Particulate matter
PMI	Particulate matter index

R&D	Research and development
RCEM	Rapid compression expansion machine
RCM	Rapid compression machine
RON	Research octane number
SCO	Spray/combustion—optical imaging
SI	Spark ignition
SNL	Sandia National Laboratories
SS	Sprays—simulation
SX	Sprays—X-ray imaging
TRL	Technology readiness level
UM	University of Michigan
U.S. DRIVE	U.S. Driving Research and Innovation for Vehicle efficiency and Energy sustainability
VCR	Variable compression ratio
VTO	Vehicle Technologies Office
YSI	Yield sooting index

6. Materials Technologies

To strengthen national security, enable future economic growth, support energy dominance, and increase transportation energy affordability for Americans, the Vehicle Technologies Office (VTO) funds early-stage, high-risk research. The research will generate knowledge that industry can advance to deploy innovative energy technologies to support affordable, secure, reliable and efficient transportation systems across America. VTO leverages the unique capabilities and world-class expertise of the national laboratory system and works with partners across industry and academia to develop new innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures and better powertrains; and energy efficient mobility technologies and systems, including connected and automated vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement. VTO is uniquely positioned to address early-stage challenges due to its strategic research partnerships with industry (e.g., the U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise. These partnerships prevent duplication of effort, focus U.S. Department of Energy (DOE) research on the most critical research and development (R&D) barriers, and accelerate progress. VTO focuses on research that industry either does not have the technical capability to undertake on its own—usually because there is a high degree of scientific or technical uncertainty—or it is too far from market realization to merit sufficient industry emphasis and resources.

The Materials Technology subprogram supports vehicle lightweighting and improved propulsion (powertrain) efficiency through early-stage research & development (R&D) to discover and further understanding of how to manipulate and use novel materials and enabling technologies for industry to develop and deploy light- and heavy-duty vehicles. The Materials Technology research portfolio supports the Vehicle Technologies goals of affordable transportation and energy security. Reducing the weight of a conventional passenger car by 10% results in a 6%-8% improvement in fuel economy and similar benefits are achieved for battery electric and heavy-duty vehicles. To achieve this, research focuses on activities that have a high degree of scientific or technical uncertainty, or that are too far from market realization to merit sufficient industry emphasis and resources. The Materials Technology subprogram accomplishes its technical objectives through research programs with academia, national laboratories, and industry.

Lightweight Materials Technology supports research in advanced high-strength steels (AHSS), aluminum (Al) alloys, magnesium (Mg) alloys, carbon fiber composites (CFCs), and multi-material systems with potential performance and manufacturability characteristics that greatly exceed today's technologies. This includes projects addressing materials and manufacturing challenges spanning from atomic structure to assembly with an emphasis on establishing and validating predictive modeling tools for materials applicable to light- and heavy-duty vehicles. Propulsion Materials Technology supports research to develop higher performance materials that can withstand increasingly extreme environments and address the future properties of a variety of relevant, high-efficiency powertrain types, sizes, fueling concepts, and combustion modes.

Subprogram Feedback

DOE received feedback on the overall technical subprogram areas presented during the 2018 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied.

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year?

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: mat918
Presentation Title: Materials Technologies Overview
Principal Investigator: Felix Wu (U.S. Department of Energy)

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:
This reviewer described the strategy as well-covered and defined for both Lightweight Materials and Power Train Materials.

Reviewer 2:
The reviewer replied positively; the strategy for both lightweight and propulsion materials were covered well, and quantitative targets and roadmaps were shown.

Reviewer 3:
This reviewer remarked that the presentation adequately covered DOE efforts in the area of materials.

Reviewer 4:
The reviewer asserted that the two goals of lightweighting the glider and improving powertrain materials were adequately described, but the strategy was modestly addressed. The presentation gave the roadmap, but not a strategy of how to move forward. This reviewer wanted to see more vision of where the work needs to be done.

Reviewer 5:
This reviewer stated no and recommended that future presentations focus on strategic direction versus historical accomplishments.

Question 2: Is there an appropriate balance between near- mid- and long-term research and development?

Reviewer 1:
The reviewer stated yes; the balance was maintained very well. For example, some of the materials do not make an effective business case at the present time, but given the technology progress in the next few years, these materials can become viable. Any lack of research to understand the use of these materials becomes a big hurdle in the future. This reviewer observed a good balance between the mid- and long-term research and development (R&D) in the materials section.

Reviewer 2:
Based on priorities and technology readiness levels (TRL), this reviewer commented that the program is well-balanced between short- and long-term goals.

Reviewer 3:
This reviewer found it difficult to assess an appropriate balance between near-, mid-, and long-term R&D because research timelines were not presented.

Reviewer 4:
The reviewer indicated no; focus was predominately on accomplishments and there was a lack of mid- and long-term planning.

Reviewer 5:
Little description between the near-, mid-, and long-term research was reported by this reviewer, who added that this point was not covered well.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer responded positively and explained that the important issues (e.g., cost, predictability tools for optimum design, joining, recycling, etc.) were clearly identified for each of the material systems.

Reviewer 2:
This reviewer stated well done; primary issues for the wide range of material systems were identified and priorities were established.

Reviewer 3:
The reviewer remarked that important challenges and the most important technological opportunities to address those challenges were clearly identified.

Reviewer 4:
The important issues were clearly identified from this reviewer's perspective.

Reviewer 5:
This reviewer stated no: 10% mass reduction results in 6%-8% reduction in fuel; and higher combustion pressures result in increased high temperature material properties. The reviewer emphasized that the lower relative cost of increasing combustion efficiency resulting from increased cylinder pressure and fuel reduction due to mass reduction relative to competing technologies (e.g., electrification and lightweighting) is important to illustrate. Lightweighting is around $2.50/pound (lb) saved and the cost of batteries at $240/kilowatt-hour (kWh) is equivalent to $5/lb saved. The reviewer explained that if the cost of batteries is reduced to $120/kWh, lightweighting at $2/lb saved is a push.

Additionally, the reviewer opined that the environmental impact imposed by the production of Mg using electrolytic reduction and the high production rates of ZEK100 warm-formed Mg sheet need to be identified as a Mg cornerstone. Rather, VTO is proposing AZ31 sheet, which uses the 3 min/part quick plastic forming process.

Although the recyclability and short molding times associated with carbon fiber-reinforced polymer (CFRP) need to be identified as a cornerstone, this reviewer noted that VTO is proposing thermoset resin and continuous fiber/fabric. The reviewer highlighted the environmental impact and long cycle time associated with thermoset.

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:
This reviewer stated yes; the effort to collaborate with other consortiums (e.g., like LightMAT) and advanced facilities available at the national laboratories were provided.

Reviewer 2:
The reviewer described future research areas as clearly identified and acknowledged that specifics were not provided because this was an overview presentation.

Reviewer 3:
This reviewer indicated that the Materials Technology Roadmap identifies key issues related to the broad range of automotive materials and research needs. However, plans to address these specific needs were not detailed.

Reviewer 4:
The reviewer reported that the only plans identified are the LightMAT and HPC4Mfg programs, which can enable future projects, but are not clear plans for addressing issues.

Reviewer 5:

This reviewer stated no. Firstly, the reviewer pointed out that the carbon (C) footprint associated with reduction of magnesium oxide (MgO) using the Pidgeon process is not identified or listed as an issue/challenge. Additionally, the supply risk associated with Mg ingot, as well as the cost and environmental impacts of Mg reduced using electrolytic reduction in the U.S. and Canada are not discussed.

Secondly, this reviewer highlighted that the long cycle time (3 min/part) of using "quick plastic forming process" to form Mg sheet and the issue of long cycle time associated with quick plastic forming of AZ31 Mg sheet are not identified as issues/challenges. Cycle time results in high cost; the alternative cycle time (10 sec/part) of warm forming ZEK100 Mg sheet is not presented.

Thirdly, the reviewer noted that recyclability of thermoset resins (1 useful life) is not identified as an issue/challenge. The lack of recyclability presents high C footprint, and the alternative recyclability of thermoplastic resin is not presented.

Fourthly, the reviewer indicated that long cycle time (3 min/part) of using "compression molding process" to form CFRP is not identified as an issue/challenge. The alternative of injection molded chopped fiber thermoplastic is not presented.

The reviewer offered the following alternative solutions: electrolytic reduction of MgO, ZEK-alloy enables warm forming (10 sec/part), and domestic supply of ingot and sheet; or injection molding process using chopped fiber and thermoplastic resin, which addresses cost and recyclability of thermoset and continuous fiber. With respect to the latter proposed solution, the reviewer acknowledged the uniform distribution and orientation of CF challenges that need be addressed.

Question 5: Was progress clearly benchmarked against the previous year?

Reviewer 1:

This reviewer commented that more information may be needed regarding the progress achieved. Also, it may be difficult to provide progress in a year-long time span because these efforts usually become fruitful with large improvements after a few years.

Reviewer 2:

There was no clear benchmarking of technical progress from 2017 to 2018 observed by this reviewer, just the budget numbers.

Reviewer 3:

This reviewer responded negatively and reported that benchmark data was not presented.

Reviewer 4:

The reviewer remarked that broad program areas were covered and specific comparisons to last year's work were not performed.

Reviewer 5:

This reviewer responded negatively and indicated that this does not appear to be an objective of this particular presentation.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:

This reviewer stated yes; the materials technology mission of automobile lightweighting directly benefits fuel economy, energy independence, and emissions, which are broad problems that VTO is trying to solve.

Reviewer 2:
While specific technical programs are not listed or addressed by the MAT918 overview, this reviewer commented that the breadth of technical projects presented at the AMR clearly addresses the broad range of technologies outlined by the presentation. It is apparent to this reviewer that VTO is funding relevant research in all of the challenge areas identified by this presentation.

Reviewer 3:
It was clear to this reviewer that the program is well thought-out. Some new, well-considered programs also were introduced (e.g., LightMAT). The reviewer advised that VTO judiciously invest in high-performance computing (HPC)-type programs because several materials development problems are not scalable on big, powerful machines. This is different from problems like finite element modeling or computational fluid dynamics where more computing power provides more refined answers.

Reviewer 4:
The reviewer responded negatively and pointed out that many VTO projects are focused on Mg/steel, CFRP/steel, AZ91 Mg alloy, continuous fiber, and thermoset resins.

Reviewer 5:
This reviewer explained that the projects are not identified by category or by technology, and there is no information on a strategy or overarching plan to reduce weight and improve platinum (Pt) materials.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:
The reviewer emphatically replied yes and described the materials technology program as very focused, well-managed, and very effective in addressing VTO needs.

Reviewer 2:
This reviewer stated yes; the program area most certainly appears to be focused, well-managed, and effective in addressing VTO needs. With specific lightweight materials program work in all areas of need and progress reported throughout the AMR, the reviewer asserted that the management team is doing an adequate job in a focused and effective manner.

Reviewer 3:
The reviewer observed a critical program that takes industry input to develop roadmaps and reports and then manages an effective portfolio to address the challenges identified in the roadmaps.

Reviewer 4:
This reviewer stated no.

Reviewer 5:
The program did not appear to be well-focused from this reviewer's perspective. The roadmap is a good start, but the reviewer noted that funding or accomplishments against this roadmap were not presented here.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:
The reviewer described the following as strengths: the VTO Materials technology program for automobiles is better managed to get results compared to materials programs in other sectors like aerospace; the complexity of VTO Materials program challenges compared to other programs; and the probable value of technology

developed under VTO auspices compared to other sectors like aerospace. This reviewer stressed that reduction in funding could be a significant weakness going forward.

Reviewer 2:

The reviewer commented that a key programmatic strength is the strong industry interaction and the weakness as presented was a focus on HPC without justification of how and/or why this is a critical area for materials development. Further, it was difficult for this reviewer to judge individual projects based on the examples provided.

Reviewer 3:

Because the projects are not clearly identified, the reviewer was at a loss to answer this question. What the Advanced Joining Consortium does as well as its corresponding projects and/or budget was unclear to this reviewer. The efforts for HPC4Mfg and LightMAT are good vehicles for addressing point needs, but are not set up to make strategic leaps forward in lightweighting or powertrain materials.

Reviewer 4:

This reviewer found insufficient content in the MAT918 presentation to effectively comment.

Reviewer 5:

The demonstrated ability to focus Oak Ridge National Laboratory (ORNL) and Pacific Northwest National Laboratory (PNNL) on topics was described by this reviewer as a key strength. Conversely, the reviewer identified the following weaknesses: many CFRP projects focus on thermoset resins and continuous CF; many Mg projects focus on AZ91 alloy; joining themes are focused on AZ91 Mg alloy and joining Mg and CF to steel; and funding is aimed at supporting lab research. This reviewer explained that industry receives no cash and only provides in-kind labor, which limits industry engagement.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:

This reviewer stated yes; projects related to advanced materials (e.g., CFCs, Al, and high-strength steel [HSS]) and joining of dissimilar materials are game changing for automotive industry vehicle lightweighting and improved fuel economy.

Reviewer 2:

The overall direction and scope of the program were encouraging to this reviewer, although no specific project related information was presented.

Reviewer 3:

This reviewer commented that there was not sufficient content in the MAT918 presentation to effectively comment.

Reviewer 4:

The reviewer was at a loss to answer this question because there was no project information.

Reviewer 5:

This reviewer stated that these projects do not represent novel and/or innovative ways to approach these barriers appropriately.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:
The reviewer remarked that this program has been successful in engaging with national laboratory, industry, and university partners in the past and continues to do that.

Reviewer 2:
This reviewer responded positively and reported that the materials program adequately engages academia, national laboratories, and industry.

Reviewer 3:
The reviewer indicated that national laboratories, domestic automotive original equipment manufacturers (OEMs), tier one suppliers, academic institutions, and subject matter experts all participate. While the mix of involvement from each type of partner may be questioned, this reviewer described it as comprehensive and complete.

Reviewer 4:
This reviewer stated yes, though university and industry partner engagement are limited due to lack of funding received by industry.

Reviewer 5:
The community is strong and interested as noted by this reviewer, who also acknowledged the partners and typical players from other AMR presentations. The reviewer further observed waning engagement the last couple of years, perhaps because the vision is not clear enough.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:
Based on participation level, it was clear to this reviewer that the collaboration is both effective and productive.

Reviewer 2:
The reviewer responded positively and observed effective collaborations.

Reviewer 3:
This reviewer stated yes.

Reviewer 4:
The reviewer asserted that program personnel engage well with industry and university personnel, but pointed out a lack of industry engagement due to lack of funding.

Reviewer 5:
This reviewer expressed that it was hard to tell.

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:
The reviewer was encouraged to see materials development being emphasized; it is an area where continued emphasis will bear fruit for the program. This reviewer also suggested that efforts in the area of additive manufacturing will be useful.

Reviewer 2:
No glaring gaps were observed by this reviewer. The program is well-conceived and the breadth is encompassing. The reviewer recommended more attention on means and methods of low-cost manufacturing,

thereby enabling implementation of key lightweighting and powertrain technologies, which may be the only component potentially benefitting from greater focus.

Reviewer 3:

This reviewer indicated that the materials program should add some battery system materials to its portfolio to improve design and cost efficiency of battery systems.

Reviewer 4:

The reviewer reported that the roadmap identifies gaps and opportunities for lightweight vehicle needs.

Reviewer 5:

This reviewer stated yes and emphasized that the energy efficiency portfolio gap is focusing on system efficiency. One group works on battery chemistry, another on charging, another on motor design, and another on lightweight materials. The reviewer also noted the following gaps: vehicle system efficiency; and driveline efficiency (design and reduced frictional losses)

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:

This reviewer could not think of any topics that are being inadequately addressed.

Reviewer 2:

The reviewer stated well done and was very impressed with the breadth of topics reviewed at the AMR. This reviewer pointed out there is a C-centric focus to the non-metallic lightweighting materials efforts, and suggested possible value in considering a range of reinforcements, hybrids, or simple geometry to exploit other low specific gravity engineering materials, including glass fiber reinforcements.

Reviewer 3:

This reviewer remarked that some examples of existing project successes would be useful for future overview presentations.

Reviewer 4:

System efficiency and driveline efficiency/energy recovery were highlighted by this reviewer.

Reviewer 5:

There appeared to be a lack of implementation and verification projects from the reviewer’s perspective. The best project area would integrate a number of previously developed technologies into a demonstration and/or verification project to see if the solutions were robust.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:

This reviewer advised that it may be useful to consider a set of topics that begin large-scale integration of lightweighting technologies. The reviewer further explained that this would achieve significant part integration in monocoque body and chassis design such that the expected higher material costs of lightweight composites and metal alloys can be offset by significant part count and integration of major sub-assemblies.

Reviewer 2:

The question was difficult for this reviewer to answer because the funding is unclear against the roadmap. The reviewer observed great need for an integration and verification project to combine a number of technologies.

Reviewer 3:
This reviewer recommended additive manufacturing and materials development as two key areas to emphasize.

Reviewer 4:
The reviewer listed the following areas that this program area should consider funding to meet overall programmatic goals: driveline efficiency; overall vehicle system efficiency; and cradle-to-grave lifecycle.

Reviewer 5:
This reviewer identified the following areas: advanced lightweight materials for battery systems; lightweight material architectures for battery vehicles to meet performance requirements; CF component certification protocols development for automotive industry; and prognosis of composite systems manufacturing to reduce manufacturing costs.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:
The reviewer asserted that existing approaches are sufficient and hoped for sustained funding in the key area of materials as part of the portfolio.

Reviewer 2:
This reviewer recommended more funding and more collaboration with the OEMs.

Reviewer 3:
The reviewer suggested challenging projects to integrate and verify the technologies.

Reviewer 4:
This reviewer explained importance of aligning the commercial needs that automotive OEM's must meet with the technical objectives established by the program area. Lightweighting is not necessarily the first thing that comes to mind new vehicle consumers. The reviewer opined that more public education such that consumers demand products aligning with these attempts to improve efficiency, reduce embodied energy, and expand lightweight material use can go a long way toward positively affecting the products that roll off the assembly line going forward. DOE can drive the technical program by solicitation and funding, but the reviewer asked what the point would be if this does not result in consumer-accepted products.

Reviewer 5:
The reviewer noted the following: overall system efficiency; driveline efficiency; and cradle-to-grave lifecycle.

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:
This reviewer suggested more communication of the knowledge and improvements achieved from this materials program to the entire automotive industry supply chain for more efficiency.

Reviewer 2:
The reviewer suggested that the presentation itself would benefit from a listing of the active program area projects and the specific goals expected from each. It would provide a holistic view of the program area activities and enable a more effective "gap" analysis. The reviewer clarified that this was not a very strong criticism by any means.

Reviewer 3:

This reviewer advised that emphasizing early stage, national laboratory research that can be translated to industry in later years will lead to out-of-box solutions. Sustained funding at the national laboratories will be important to achieve the programmatic goals.

Reviewer 4:

This reviewer remarked that a clear vision of success would greatly help focus this effort.

Reviewer 5:

The reviewer commented to enforce go/no-go milestones. The reviewer asserted that this should be an administrative decision to continue funding.

This reviewer also suggested expanding the theme to mobility systems, which includes alternate forms of transport (e.g., drone delivery, drone personal transport, and first mile/last mile transit in an urban environment). The project funds would need to sufficiently support a project team comprised of multiple disciplines, industry, university, and government lab personnel over a period between 3 and 5 years. The reviewer commented that the Multi Material Lightweight Vehicle (MMLV) project size is a good example (i.e., $20 million over 3 years, 50% funded by DOE, 50% by industry). The reviewer also advised to increase the funding ratio to 80% if VTO wants to encourage more university or DOE lab involvement.

Battery-powered drone personal transport development was offered by this reviewer as a project example. The project would deploy the latest lightweight materials and joining processes including CFRP, Mg, friction stir welding (FSW), artificial intelligence (AI), and chemical-toughened glass.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0*). In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 6-1—Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat053	High-Temperature Engine Materials: Valve Materials Subtask	G Muralidharan. (ORNL)	6-16	3.33	3.33	3.33	3.00	**3.29**
mat057	Applied Computational Methods for New Propulsion Materials	Charles Finney (ORNL)	6-19	3.00	2.67	2.33	2.83	**2.73**
mat060	ICME Guided Development of Advanced Cast Aluminum Alloys for Automotive Engine Applications	Mei Li (Ford)	6-22	3.38	3.25	3.00	N/A	**3.25**
mat061	Computational Design and Development of a New, Lightweight Cast Alloy for Advanced Cylinder Heads in High-Efficiency, Light-Duty Engines	Mike Walker (General Motors)	6-25	3.00	2.63	3.00	1.50	**2.63**
mat069	Lightweight High-Temperature Alloys Based on the Aluminum-Iron-Silicon System	Michelle Manuel (U. of Florida)	6-28	3.17	3.50	3.00	2.67	**3.25**
mat101	Integrated Computational Materials Engineering (ICME) Development of Carbon Fiber Composites for Lightweight Vehicles	Xuming Su (Ford)	6-32	3.13	3.38	3.13	3.13	**3.25**
mat113	Magnesium Corrosion Characterization and Prevention	Mike Brady (ORNL)	6-36	3.33	2.83	3.50	3.17	**3.08**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat117	Development and Integration of Predictive Models for Manufacturing and Structural Performance of Carbon Fiber Composites in Automotive Applications	Venkat Aitharaju (General Motors)	6-39	3.50	3.38	3.25	3.25	**3.38**
mat118	Functionally Designed Ultra-Lightweight Carbon Fiber Reinforced Thermoplastic Composites Door Assembly	Srikanth Pilla (Clemson U.)	6-43	3.00	3.13	3.25	2.75	**3.06**
mat119	Ultra-Light Hybrid Composite Door Design, Manufacturing, and Demonstration	Nate Gravelle (TPI)	6-46	3.00	3.17	3.67	3.17	**3.19**
mat122	Low-Cost Carbon Fiber Research Using Close Proximity Electromagnetic Carbonization (CPEC)	Felix Paulauskas (ORNL)	6-49	3.10	2.90	2.90	2.90	**2.95**
mat124	Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber for Lightweight Vehicles	Xiadong Li (U. of Virginia)	6-53	3.38	3.00	3.25	3.00	**3.13**
mat125	Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber	Donald Collins (Western Research Institute)	6-57	3.38	2.75	3.38	3.25	**3.05**
mat126	Room-Temperature Stamping of High-Strength Aluminum Alloys	Aashish Rohatgi (PNNL)	6-60	3.33	3.33	3.33	3.33	**3.33**
mat127	USAMP Low-Cost Magnesium Sheet Component Development and Demonstration Project	Stephen Logan (FCA)	6-64	2.88	2.88	3.38	3.13	**2.97**
mat128	Development of Low-Cost, High-Strength Automotive Aluminum Sheet	Russell Long (Arconic)	6-68	3.38	3.50	3.13	3.13	**3.38**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat129	Optimizing Heat-Treatment Parameters for 3rd Generation Advanced High-Strength Steel Using an Integrated Experimental Computational Framework	Xiaohua Hu (PNNL)	6-72	3.00	2.83	3.00	2.67	**2.88**
mat130	Enhanced Sheared Edge Stretchability of Advanced High-Strength/Ultra-High Strength Steels	Kyoo Sil Choi (PNNL)	6-76	2.88	2.75	3.00	2.50	**2.78**
mat131	Corrosion Control in Carbon Fiber Reinforced Polymer Composite—Aluminum Closure Panel Hem Joints	Brian Okerberg (PPG Industries)	6-80	2.92	3.08	3.17	3.08	**3.05**
mat132	High-Strength Steel-Aluminum Components by Vaporizing Foil Actuator Welding	Glenn Daehn (Ohio State U.)	6-84	3.67	3.50	3.50	3.50	**3.54**
mat133	Corrosion Protection and Dissimilar Material Joining for Next-Generation Lightweight Vehicles	DJ Spinella (Arconic)	6-87	3.33	3.17	3.17	3.00	**3.19**
mat134	Assembly of Dissimilar Aluminum Alloys for Automotive Applications	Piyush Upadhyay (PNNL)	6-90	3.25	3.38	3.38	3.38	**3.34**
mat135	Technology Validation of Innovative Dissimilar Materials Joining Method in Automotive Production Environment	Zhili Feng (ORNL)	6-93	3.00	3.00	3.20	2.90	**3.01**
mat136	High-Performance Computing and High-Throughput Characterizations towards Interfaces-by-Design for Dissimilar Materials Joining	Xin Sun (ORNL)	6-97	2.80	2.90	3.20	2.90	**2.91**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat137	Adhesive Bonding of Carbon-Reinforced Plastic to Advanced High-Strength Steel	Amit Naskar (ORNL)	6-101	2.90	3.10	2.90	3.30	**3.05**
mat138	Solid-State Joining of Magnesium Sheet to High-Strength Steel	Glenn Grant (PNNL)	6-105	3.50	3.30	3.00	3.30	**3.31**
mat139	Joining Magnesium Alloys to Carbon Fiber Reinforced Polymers	Scott Whalen (PNNL)	6-109	3.20	3.30	3.30	3.10	**3.25**
mat142	Metal Matrix Composite Brakes Using Titanium Diboride	Glenn Grant (PNNL)	6-113	3.33	2.83	3.33	3.00	**3.04**
mat143	Mitigating Corrosion in Magnesium Sheet in Conjunction with a Sheet-Joining Method that Satisfies Structural Requirements within Subassemblies	Aashish Rohatgi (PNNL)	6-116	3.00	3.00	3.33	2.67	**3.00**
mat144	Reducing Mass of Steel Auto Bodies Using Thin Advanced High-Strength Steel with Carbon Fiber Reinforced Epoxy Coating	Dave Warren (ORNL)	6-119	3.30	3.30	3.50	3.10	**3.30**
mat145	Joining Core Program Overview	Richard Davies (ORNL)	6-123	3.30	3.40	3.20	3.20	**3.33**
Overall Average				**3.17**	**3.11**	**3.19**	**3.05**	**3.12**

Presentation Number: mat053
Presentation Title: High-Temperature Engine Materials: Valve Materials Subtask
Principal Investigator: G. Muralidharan (Oak Ridge National Laboratory)

Presenter

G. Muralidharan, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

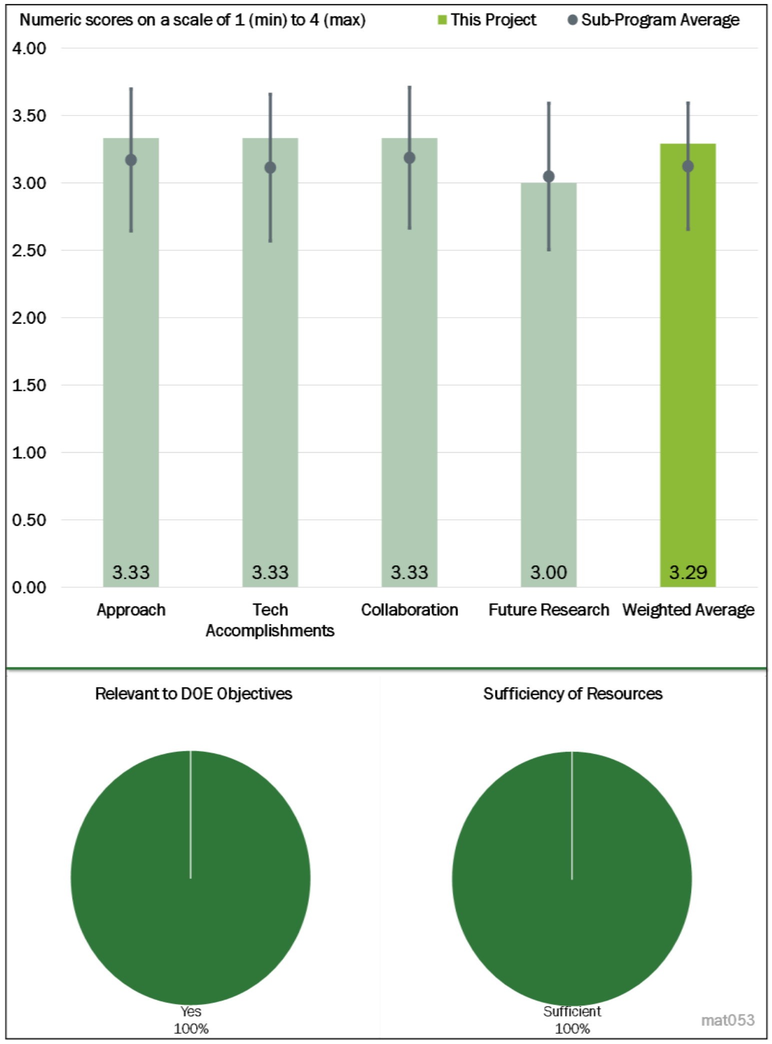

Figure 6-1 - Presentation Number: mat053 Presentation Title: High-Temperature Engine Materials: Valve Materials Subtask Principal Investigator: G. Muralidharan (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the principal investigator (PI) and the team have a good plan to investigate how to promote a higher temperature nickel (Ni)-based super alloy that can possibly avoid the degradation of γ' at increasing temperatures.

Reviewer 2:

The reviewer stated that materials allowing high (greater than 950° C) exhaust temperatures are a barrier to power density and efficiency.

Reviewer 3:

The reviewer commented that the team has made very good progress on evaluating multiple alloy combinations, from the past chromia formers to the latest alumina formers. The combination of mechanical property testing, oxidation studies, and scanning electron microscopy imaging is able to quickly evaluate and select the best designs to go forward. However, there appears to be a lack of computational thermodynamics and density functional theory work that may help with finding new elemental combinations for testing.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that Govindarajan and the team are making good progress considering this program just started. The reviewer expressed confusion about one slide that mentioned that the higher chrome led to higher alumina growth, etc. Otherwise it looks like the PI and the team are measuring everything against the benchmark.

Reviewer 2:

The reviewer commented that the team has come up with improved alloy combinations that are better than the commercial alloys. The team's alumina-forming alloys double the commercial alloys' strengths. The reviewer pointed out, however, that these alloys' strengths still need to double to compete with chromia alloys, and cost needs to be evaluated, especially with the use of cobalt.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that the PI has very good communication and coordination skills.

Reviewer 2:

The reviewer acknowledged that it is a challenging task to get specialty produced valve stock. The research team appears to be able to create the designed alloys, get them produced, heat treated, and machined for testing. The reviewer noted that required tests are carried out in a timely manner for the project to progress forward. However, the reviewer observed a lack of resources on the computational thermodynamic side that could be used to identify new compositions.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that future research focuses on developing varies alloys with potential higher strength and oxidation resistance and down-selecting the best one for larger scale testing. The reviewer saw that the selection process is fine. However, the reviewer did not see how the team intends to develop the new chemistry. From what was shown, it appears more trial and error rather than a methodical method to achieve the goal. The reviewer said that the team is now focusing on the alumina formers and although the team has made very good strides in achieving strengths, it still needs to double the strength that they have. The reviewer exclaimed, that is a lot.

Reviewer 2:

The reviewer suggested that the project team maybe incorporate carbide formers (C, chromium, molybdenum, tungsten, niobium, tantalum, titanium [Ti], and hafnium. The carbides tend to precipitate at grain boundaries and hence reduce the tendency for grain boundary sliding at higher temperatures to mitigate risk.

Reviewer 3:

The reviewer inquired what the down-selection criteria are.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that the project supports DOE objectives to create higher temperature materials to increase engine efficiencies.

Reviewer 2:

The reviewer noted that DOE objectives are based on increasing engine efficiency by enabling higher temperatures and pressures in the engine. Higher temperatures and pressures require valves to be able to sustain higher temperatures, and this project is attempting to do that.

Reviewer 3:

The reviewer pointed out that power density and efficiency are often limited due to material limits at high exhaust temperatures.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer believed that ORNL and the material suppliers have enough resources to achieve their goals. The reviewer thinks that ORNL may need to add resources in the integrated computational materials engineering (ICME) area to reach the final goal.

Reviewer 2:

The reviewer suggested asking Lou Hector, Jr., a General Motors (GM) Technical Fellow in the Chemical and Materials Systems Lab at the General Motors R&D Labs in Warren, Michigan, to join your team. The reviewer detailed that Lou conducts research in engineering materials such as AHSS and, in this reviewer's opinion, Lou could definitely apply his amazing talents to move this program in a timely fashion.

Presentation Number: mat057
Presentation Title: Applied Computational Methods for New Propulsion Materials
Principal Investigator: Charles Finney (Oak Ridge National Laboratory)

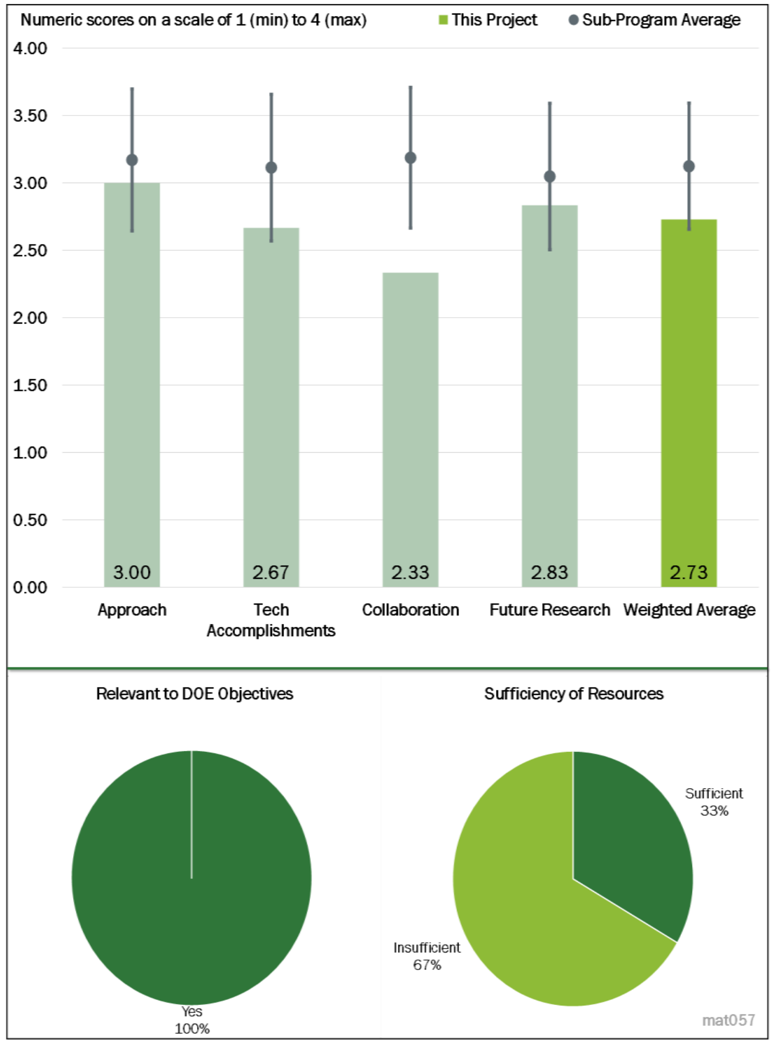

Figure 6-2 - Presentation Number: mat057 Presentation Title: Applied Computational Methods for New Propulsion Materials Principal Investigator: Charles Finney (Oak Ridge National Laboratory)

Presenter
Charles Finney, Oak Ridge National Laboratory

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer said that the project team's approach, which compares standard low-order modelling to the slower high-order modelling, is well thought of. For one, it will identify the limitations of the lower order model as well as identify the most important areas in the high order modelling. The reviewer noted that the project team is also looking at comparing multiple real materials for validation.

Reviewer 2:
The reviewer remarked that the combination of measured physical properties, complex simulations, and super computers promise to make progress on material property improvements.

Reviewer 3:
The reviewer acknowledged that the PI has a plan for the program, but opined that some upfront data material testing data requirements need to be addressed before looking at the cylinder head component specifically.

The reviewer said that Charles has looked at fatigue at higher temperatures (greater than 400°C) and claimed that the creep behavior is causing the loss of fatigue strength. However, the team needs to understand that this is a wonderful opportunity to create a mathematical model that combines both the fatigue (Coffin-Manson) and creep (power law) deformation mechanisms of the compacted graphite iron (CGI) material at high temperatures and pressures.

The reviewer suggested looking at the following equations to start: $\varepsilon = A \exp(- Q/RT)\, \sigma^n\, t^m$, where n and m are the stress and time hardening exponents, Q is the activation energy (kJ mol^{-1}), R is the universal gas constant (8.314 J $mol^{-1}K^{-1}$), and A is constant; and (delta e / 2) = $e'_f(2N_f)^c$, where delta e / 2 is the total strain amplitude, e'_f is the fatigue ductility coefficient, $2N_f$ is the number of reversals to failure, and c is the fatigue ductility exponent.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed some data, but indicated that the team also needs to look at the CGI cylinder head from a thermal dynamic point of view because the cooling, heat, and stress on the bridge between the exhaust valves are allowing a residual stress to set up in the material. The reviewer noted that the fatigue crack usually initiates at the cooling line. The reviewer observed that Charles and the team could them use the above fatigue and creep data and using a Goodman diagram-type relation determine the deformation behavior for the cylinder head.

Reviewer 2:

The reviewer noted that the development of the models is complete as well as some data analysis. However, given that the program started in 2014 and will be completed in 2019, the project has only shown very little results. The reviewer remarked that the team still needs to get the high-order simulations into the high-power computer.

Reviewer 3:

The reviewer was unclear where the creep information came from. The reviewer noted that progress is being made toward the ultimate program goal.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer observed that the presentation listed partners, but it was not clear to this reviewer what their role is and how they contribute to the project.

Reviewer 2:

The reviewer remarked that the program is just starting so it appears to the mostly ORNL-centric at this time. However, the reviewer suggested inviting Westmoreland Mechanical Testing and Research, Inc. to assist with some of the fundamental material testing. The reviewer also suggested maybe a casting simulation partner (Magmasoft, EKK, etc.) to determine the quality of the CGI cast material, etc.

Reviewer 3:

The reviewer acknowledged that the ORNL team appears to be working with the simulation group well, but the reviewer did not see much in the way of results with the OEMs. The reviewer asked what the OEM's are providing in the project, and if they are getting information that is useful to them. The reviewer remarked that there needs to be more results from the high-order simulations to show what is needed for a material.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer observed good future plans, and that it would be good to apply this same approach to an Al block and cylinder head.

Reviewer 2:
The reviewer stated that this is a very interesting but challenging program for ORNL. The team needs to understand the fundamental material deformation behavior and then can offer improvements to the powertrain component itself.

Reviewer 3:
The reviewer said that fully implementing models is critical to the project and is a stated future goal. The reviewer cited that the team plans to get full creep/fatigue for CGI, but the team also needs to get results for gray cast iron. Furthermore, rather than just getting results, what is needed, and the purpose of the project, is identifying what is needed in future materials. The reviewer specified what are the limitations in horsepower with thermoconductivity, strength, and fatigue strength; and at what temperature is fatigue strength most important.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer agreed that tis work supports the DOE objectives by the development of more efficient engines that operate at higher temperatures and pressures.

Reviewer 2:
The reviewer noted that improved materials can lead to improved engine designs for increased efficiency.

Reviewer 3:
The reviewer said that it is easy to say that we need better materials for higher power engines, however, materials always have tradeoffs of one property for another. The reviewer pointed out that engine simulations need to be used to identify material weaknesses and develop both design and materials strategies, and that this work aims to do that.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked that resources are adequate for the project.

Reviewer 2:
The reviewer suggested bringing in a CGI industry expert(s) as early as possible in order to develop a strategy going forward.

Reviewer 3:
The reviewer said that the high-order simulations are moving too slowly. Because the team cannot get the simulations running on the high-power computers, the team appears to be limited on what can be accomplished.

Presentation Number: mat060
Presentation Title: ICME Guided Development of Advanced Cast Aluminum Alloys for Automotive Engine Applications
Principal Investigator: Mei Li (Ford)

Presenter
Mei Li, Ford

Reviewer Sample Size
A total of four reviewers evaluated this project.

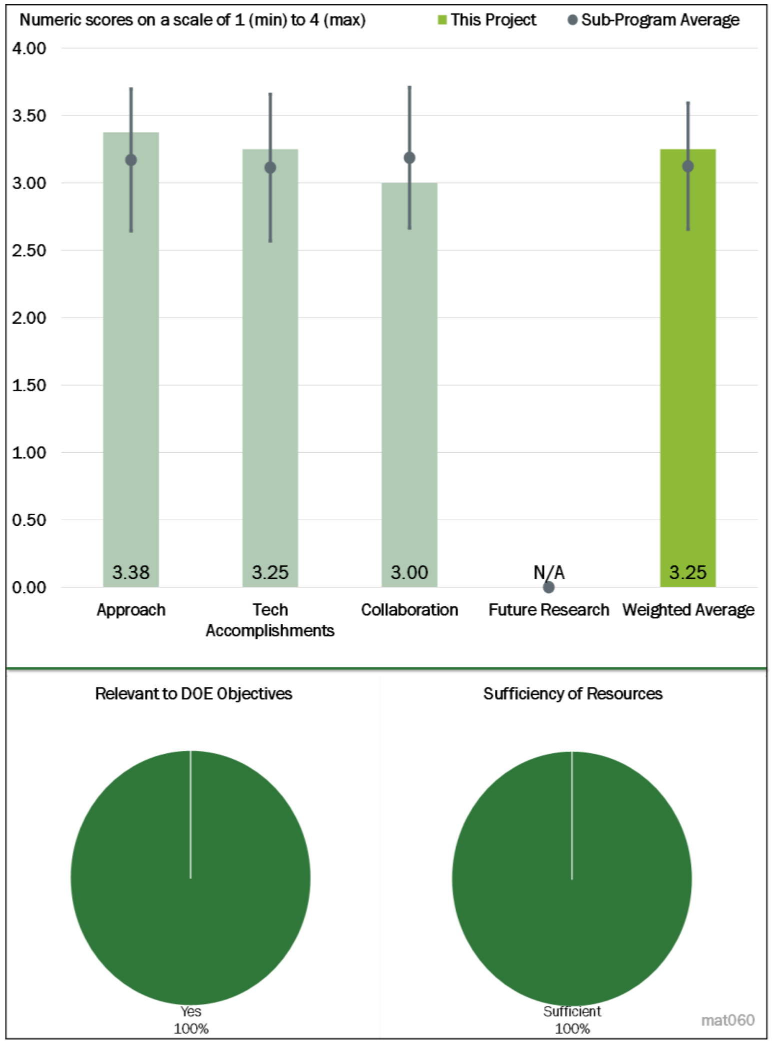

Figure 6-3 - Presentation Number: mat060 Presentation Title: ICME Guided Development of Advanced Cast Aluminum Alloys for Automotive Engine Applications Principal Investigator: Mei Li (Ford)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer remarked that the project was well-designed and thorough. The PI and her team were obviously very capable and had a clear understanding of how to apply ICME methods to the targeted materials. The reviewer described that when the results did not lead to the original goals, the team made a high value pivot to successful development of two new alloys and the associated heat treatments. The reviewer noted that both alloys were demonstrated on prototypes. A quite thorough gap analysis was provided in the presentation, although unfortunately there was not time to discuss during the presentation. The reviewer said that frankly, this was such a valuable presentation for discussion of ICME that it should have been given a full time slot at the meeting, rather than only 15 minutes.

Reviewer 2:
The reviewer said that the approach is good to combine alloy simulation with casting trials and testing parts.

Reviewer 3:
The reviewer acknowledged that this was the very end of the project. The reviewer said that it appeared that Mei Li and the Ford team did a very good job planning the ICME approach to vanadium (V) and zirconium to Al high-temperature alloys. The project team looked at increasing the strength by investigating L12-structured Al_3Zr phase.

Reviewer 4:
The reviewer said that as this project is wrapping up, few details were provided in the presentation to judge the approach.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer detailed that two new alloys were developed and demonstrated on prototype components. The reviewer said that is an excellent return on investment in only 4 years, and that the real proof of accomplishment will be eventual deployment of one or more of these alloys.

Reviewer 2:
The reviewer was impressed that Mei Li and the team took on so many tasks in a single R&D program, including alloy development for both low-pressure semi-permanent mold, and high-pressure die casting, subsequent heat treatment, etc.

Reviewer 3:
The reviewer noted good results with an improvement in alloy strength performance.

Reviewer 4:
The reviewer said that the investigators successfully developed an alloy and demonstrated these alloys on prototype components. The reviewer said that the presentation was successful in showing that results were received, but the insight that these results allowed the investigators to make were not always clear. This was particularly true in the ICME component of the project. The reviewer was not left with the impression that the computational work was "integrated," nor how these insights would be expanded upon or shared. The reviewer described that one of the more significant results expressed here and echoed in other talks was the observation that yield and ultimate strength were not the relevant properties to target as was set out in the initial program call, but that the fatigue properties were more relevant.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer found that the approach was very good and should be an example of a cross-functioning team of raw material producers, a casting simulation programmer, casting supplier, and non-ferrous ICME academia programs.

Reviewer 2:
The reviewer said that the roles and tasks taken on by the different partners were not clear.

Reviewer 3:
The reviewer remarked that partners were listed but it was not clear how partners are integrated into the project and what their roles and responsibilities are.

Reviewer 4:
The reviewer commented that the role of Magma was clear, but the roles of Alcoa, Nemak, and the University of Michigan were less clear.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the project ended.

Reviewer 2:
The reviewer remarked no future research was identified.

Reviewer 3:
The reviewer commented that the project is complete so no future work was outlined.

Reviewer 4:
The reviewer said end of project

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer agreed yes, this project is an excellent example of DOE strategically investing to stimulate and support high-risk/high-value materials development efforts to achieve superior new structural materials capable of withstanding more severe operating environments, thus supporting higher efficiency transportation technologies.

Reviewer 2:
The reviewer remarked that this work supports the DOE objectives by the development of lightweight powertrain materials.

Reviewer 3:
The reviewer commented that if cylinder head material can be improved, then engine designers can leverage this to reduce engine weight or improve engine efficiency. Both of these can reduce fuel usage.

Reviewer 4:
The reviewer stated that Al alloys that are stable at higher temperatures are relevant.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the team did a good job measuring the effects of the alloying elements against the benchmarks in both the theoretical and then actual experiments.

Reviewer 2:
The reviewer found that this project was adequately funded.

Reviewer 3:
The reviewer commented that resources and time were impressive, but still barely sufficient to develop new alloy concepts, although not quite sufficient to fully develop them. However, according to the reviewer this 5-year effort was an extremely rapid development process in the context of structural alloy development.

Reviewer 4:
The reviewer remarked that in some ways, the correct response would be “not applicable” as the project is ending.

Presentation Number: mat061
Presentation Title: Computational Design and Development of a New, Lightweight Cast Alloy for Advanced Cylinder Heads in High-Efficiency, Light-Duty Engines
Principal Investigator: Mike Walker (General Motors)

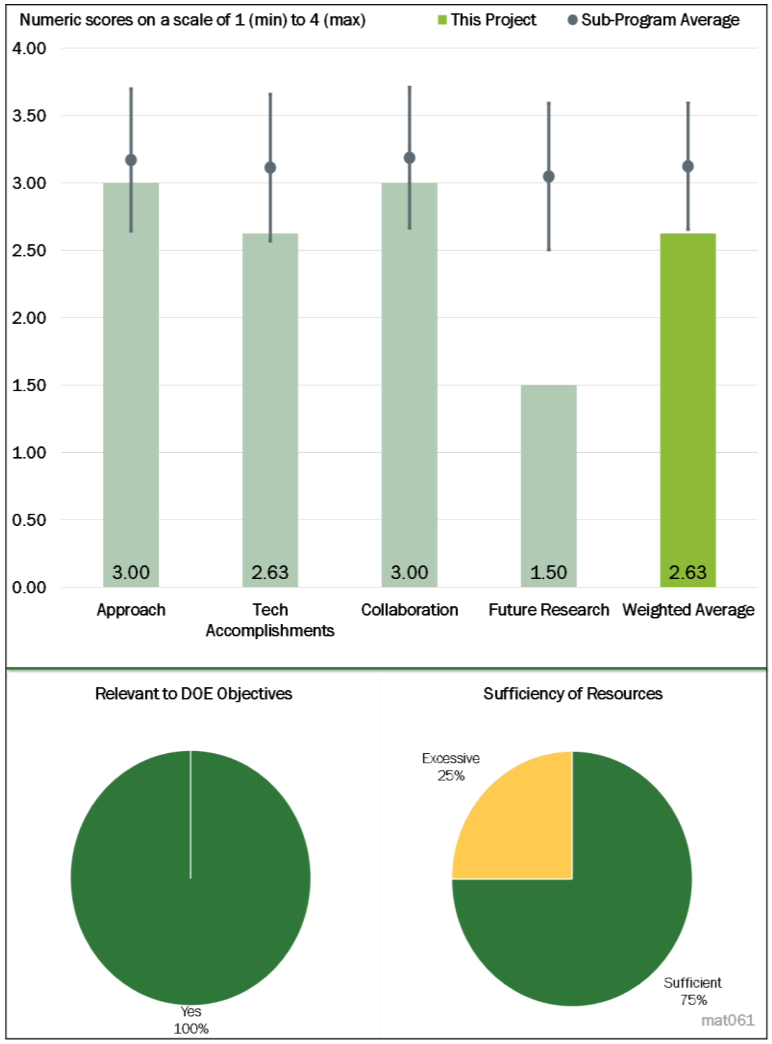

Figure 6-4 - Presentation Number: mat061 Presentation Title: Computational Design and Development of a New, Lightweight Cast Alloy for Advanced Cylinder Heads in High-Efficiency, Light-Duty Engines Principal Investigator: Mike Walker (General Motors)

Presenter
Mike Walker, General Motors

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer pointed out that this was the very end of the program, and that it appeared the PI and the GM team did a good job planning the ICME approach to stabilizing the Q-phase in Al high-temperature alloys. The project team looked at increasing the strength by adding slower thermal diffusing alloying elements such as V and Ti.

Reviewer 2:
The reviewer said that the approach was thorough and the highly qualified team was well-suited for the effort. The team chose a high-risk strategy of an alloy with a stabilized Q-phase. The team achieved a significant advancement in alloy properties, but strength targets were not. The Q-phase proved not capable of providing the anticipated strengths at peak temperature. The reviewer pointed out that this outcome demonstrates the risk and difficulties associated with developing new materials. The reviewer said that the presenter did a very good job of making the case that fatigue strength was an even more important factor than yield strength (YS), ultimate tensile strength, and peak temperature.

Reviewer 3:
The reviewer said that this project is wrapping up, so the approach was not the focus of the presentation.

Reviewer 4:
The reviewer noted that testing new alloys is necessary to find better alloys.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the approach was good only during the ICME. The lattice frequency (temperature = 0 Kelvin) was not part of the overall computations and when the data were compared to the actual experiments, the team had issues reconciling the differences. The reviewer observed good progress and very interesting casting and fatigue results (the reviewer pointed out that it takes a long time to run fatigue testing).

Reviewer 2:

The reviewer commented that technical accomplishments were harder to discern as the presentation confusingly uses two different numbering schemes: alloy 1/2/3 and baseline 1/2. The reviewer noted that two trial alloys were developed and prototype castings were made. The reviewer pointed out that one of the more significant results that was expressed here and echoed in other talks was the observation that YS and ultimate strength were not the relevant properties to target. Processing parameters and fatigue properties were more relevant.

Reviewer 3:

The reviewer said that no alloys have been identified that improve high cycle fatigue.

Reviewer 4:

The reviewer commented that advances in high-temperature alloy properties were clearly achieved, and a very nice body of work on fatigue properties was conducted. The reviewer said it was clear that defect control during casting is a dominant issue that deserves more technical attention in future materials and processing studies.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer was clear that numerous team members had substantial roles, particularly Questek and Northwestern University. The integration of their modeling and characterization capabilities with GM's design, manufacturing, and metallurgical expertise created a powerful team.

Reviewer 2:

The reviewer saw good collaboration within the existing team, but suggested that the team needed to add a more advanced casting simulation supplier in order to have run more casting simulations (e.g., Magmasoft, EKK, etc.) to determine the effect of the semi-permanent mold sand cooling rate on the fatigue/SDAS behavior on the material.

Reviewer 3:

The reviewer suggested that an industrial casting supplier could be added to address processing impacts on the behavior of the alloy.

Reviewer 4:

The reviewer said that though project roles were described, linkages between different groups and how the data were used was not as clear.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that the project ends June 2018. The future work identified seems reasonable and/or likely already complete.

Reviewer 2:
The reviewer said that when looking at fatigue variability, it appears to have surfaced late in the program. Some upfront screening using the University of Michigan's (J. Wayne Jones) ultrasonic frequency (20 kHz) fatigue testing might have been useful tool in order to mitigate risk.

Reviewer 3:
The reviewer said that the project is complete.

Reviewer 4:
The reviewer was not clear how the future plans will address the shortcomings of the proposed alloys so that the project objectives can be met.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented that development of new, more robust alloys for more severe engine operating environments supports DOE goals of higher transportation efficiencies.

Reviewer 2:
The reviewer cited development of Al alloys with improved properties at higher temperatures.

Reviewer 3:
The reviewer commented that this work supports DOE objectives by the development of lightweight powertrain materials.

Reviewer 4:
The reviewer said that if cylinder head materials can be improved, then engine designers can leverage this to reduce engine weight or improve engine efficiency. Both of these can reduce fuel usage.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer observed good resources expect maybe asking the University of Michigan (J. Wayne Jones) to do some upfront fatigue screening testing.

Reviewer 2:
The reviewer remarked that it appears additional resources would not have significantly impacted the outcome.

Reviewer 3:
The reviewer said "not applicable" is a more correct answer, as the project is ending.

Reviewer 4:
The reviewer said that spending should be stopped because the proposed alloys have not shown improved properties and the future plans do not address this.

Presentation Number: mat069
Presentation Title: Lightweight High-Temperature Alloys Based on the Aluminum-Iron-Silicon System
Principal Investigator: Michelle Manuel (U. of Florida)

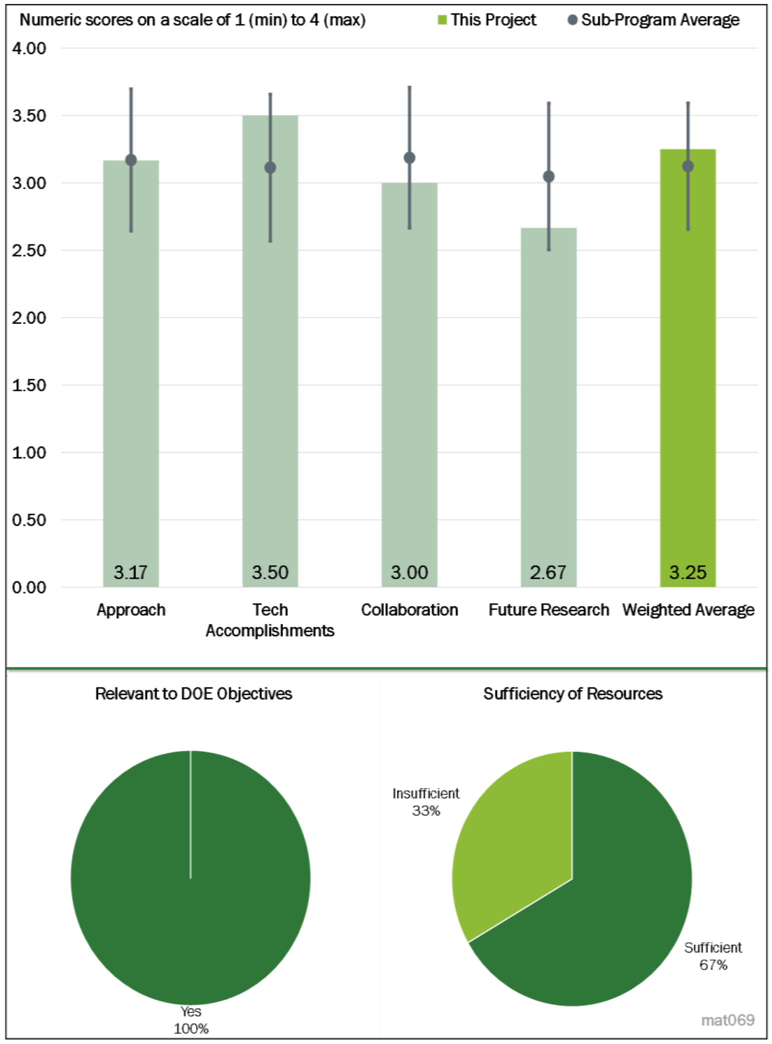

Figure 6-5 - Presentation Number: mat069 Presentation Title: Lightweight High-Temperature Alloys Based on the Aluminum-Iron-Silicon System Principal Investigator: Michelle Manuel (U. of Florida)

Presenter

Michelle Manuel, University of Florida

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the approach and research plan were explained well. The project uses computational and well-validated methods of alloy development. The reviewer remarked that the project seems high-risk/high-reward, but seems to lack go/no-go options if the project hits a significant barrier.

Reviewer 2:

The reviewer said that the approach to performing the work falls well within the category of “very good” or “excellent” from a purely academic viewpoint, but the practicality of the program as a whole seems somewhat undefined. This is not to take away from what is being accomplished, which appears to be substantial, and the qualifications of the team, which are clearly more than adequate. The reviewer said that the selection of the τ_{10} intermetallic still needs some clarification. The presentation, through the thoughtful and direct outlining of barriers given by the presenter, raised more concerns than it did to provide a clear path for success. A comparison of τ_{10} to such materials as titanium aluminides (TiAl) did little to convince the reviewer that the work has near-term relevance; the use of TiAl has been extensively researched for numerous applications and has gained little traction. The reviewer said that TiAl valves outprice valves produced by competing materials by a factor of 10-100. Nonetheless, the reviewer expressed interest in the work and looked forward to seeing progress made in this area that will elucidate the eventual use of the material. The reviewer said that at the moment, the defining of a program by microstructure seen through diffusion couples is a long distance from practical use and the reviewer would like to see that gap closed a bit.

The reviewer asked what is being drawn from the microstructures that were presented. The array of compositions side-by-side lacked some degree of visual evidence that there was a progression in microstructural behavior that could be extracted. The reviewer speculated that perhaps more magnifications showing larger areas, or detailed insets showing features of interest and their progression through a composition range, would have provided more information.

Reviewer 3:

The reviewer said that the approach to such a low TRL effort appears to be thorough, sound, and interesting. However, the core motivation for the project was not exactly clear, and somewhat unique for this meeting, because it focused on developing a narrowly stable intermetallic material for additive manufacturing of a high-temperature structural application that had not yet been identified. The reviewer noted that the objective of meeting or exceeding the high-temperature performance of a Ni-base superalloy is a noble goal. The reviewer was not clear from the presentation why the project team anticipated the alloy to be able to exceed the property set of Ni-based superalloys. For example, tensile properties for $Al_4Fe_{1.7}Si$ were shown to be superior to pure Ti and some variant of TiAl, but the temperature of measurements were not indicated, nor was the ductility. The reviewer acknowledged that the project is certainly at an early stage development, but it would have been more convincing to see a clearer presentation of what property set for $Al_4Fe_{1.7}Si$ was available to motivate this study. The emphasis on targeting this hexagonal closed packed (HCP) material for future laser printing was also interesting, because such laser-based processes are known to induce severe residual stresses—which are particularly problematic for intermetallics. The reviewer also pointed out that it seems the material is intended for higher temperature applications, but the issue of environmental resistance was not addressed or indicated as being of concern.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer identified great progress on the design/modeling component as well as the characterization of diffusion interfaces—these are critical aspects in this program. The screening component and equilibrium phase diagram analysis are also well-executed.

Reviewer 2:

The reviewer remarked that early stages of research have set a foundation for continued accomplishments, and that the experimental verification of the phase diagram and refinement of the thermodynamic databases seem to be good results.

Reviewer 3:

The reviewer commented that the progress toward creating greater stability in the targeted intermetallic phase was a good outcome. The combinatorial work and thermal analysis was valuable and appeared carefully conducted. The project is still early stage, so more results and accomplishments would be expected in future years. The reviewer said that because a material must be affordably manufacturable to be useful within the tight cost margins of the transportation market, the reviewer was somewhat concerned that the team had not given more thought to future larger scale manufacturing process(es) for which the new material(s) are being designed. The reviewer recognized that this observation must be balanced with the reality that this is very low TRL work in an academic setting. The reviewer cited discussion of converting from HCP to face-centered cubic structure with additions of copper (Cu) and manganese (Mn) on the last slide, but the reviewer was unclear if such work had shown promise in the combinatorial experiments where Mn was added. It will be very helpful to see tensile properties of key resultant materials, including elongation characteristics, next year. It will also be of value to see at least some preliminary data on environmental response at temperatures relevant to potential higher temperature powertrain applications.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that there appeared to be regular collaborations and communications with GM, and some neutron characterization work with ORNL.

Reviewer 2:

The reviewer said that as the majority of the work is "in house," the barrier for successful collaboration is much lower. The reviewer said that overall guidance from GM and reaching out for specific measurements from ORNL seem to be good efforts.

Reviewer 3:

The reviewer acknowledged that the lead group seems largely capable of performing the work being presented, which is certainly commendable, but the effective use of additional resources is somewhat murky. The role of ORNL in beam-line work is certainly an effective additional capability, but the role of GM in the program is not entirely clear, despite the suggestion that an impressively regular meeting cycle exists with that industrial collaborator. The reviewer inquired if any fruitful suggestions or feedback coming from those meetings. The reviewer noted that it is quite possible that interim discoveries or potential new paths fall squarely into the proprietary information category, but the reviewer questioned if GM is really enamored with regular updates on microstructures and modeling approach layouts. The reviewer was not clear how this collaboration is elevating the practicality or effectiveness of the program.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

In this reviewer's opinion, the layout of future work was both a strong point and a very weak point. There is an extremely logical flow to the tasks that were outlined, which is a strength of the project. The reviewer found, however, that the milestones and decision points lack a degree of distinct levels of accomplishment to be of any real value, despite the fact that they fit within the workscope and align well with the program overall. The reviewer said that the weakness lies in the generality of some of the areas being suggested—such as creating a list of chemistries as a go/no-go point. The reviewer remarked that one could create a list of chemistries while sitting at a desk that could be argued meets the objective of being producible or printable; it is the specific claims behind this list that would be compelling. The reviewer remarked that other areas are perfectly well-defined—such as the production of an additively manufactured specimen. The reviewer commented that nothing is left to speculation or hand-waving in that type of milestone.

Reviewer 2:

While the reviewer thought this project is good and should continue, the reviewer believed there are several items that could reduce the risk of this project. The reviewer detailed that as part of the question and answer, the PI indicated the team's work thus far indicated that this alloy may be castable. That seems like an important research avenue to explore, as it would reduce cost to fabricate the parts and/or allow for more parts to be manufactured at a time. While the reviewer granted that casting is non-trivial, going through the additional steps for additive manufacturing (task 7, task 8) seems to invite problems that the alloy design may have already solved. The reviewer cited as one of the unexplored risks the brittleness of the alloy. The majority of intermetallics are notoriously brittle, which will affect their relevance for fatigue environments. The reviewer said that adding screening tests (either computational or experimental) that could be conduced to assess the brittleness of the alloy may help direct the alloy design to more rapid industrial use.

The reviewer expressed concern about the validation planned between task 8 and task 9. It seems that the elastic constants predicted in task 9 will be single crystal constants (3 for hexagonal), while the measurements performed in task 8 will likely be on highly oriented (due to additive manufacturing) polycrystal samples that may have additional phases and will only provide a single value (Young's modulus [E]). The reviewer asked what will be a "successful" validation in this case. In addition, elastic modulus measurements also require large sample length for low uncertainty, which may be difficult to achieve with additive manufacturing.

Reviewer 3:

The reviewer remarked that future work is interesting as it involves manufacturing powders of morphology and volume suitable for additive manufacturing (which is not a trivial effort) and laser additively manufacturing test samples and measuring tensile properties. The reviewer said that it will be of interest to see whether stable structures are achievable at the quench rates of laser processing. The variable local thermal history due to repeated reheating during the sequential depositions of an additive process will likely impose some challenges on metastable materials dependent on rapid quenching. The reviewer said that it would seem to make sense to first test a cast quaternary material first and measure properties, prior to heavy investment in powder manufacturing of batches large enough to make additive test parts. The reviewer acknowledged that this is interesting work, but it does not seem to have clear targets. The reviewer thought that it would be very good to see a definition of more specific materials properties targets, including targeted operating temperatures and strengths at those temperatures.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that this project may develop a low-cost alloy with good high-temperature properties. The reviewer cited this project as a good example of a high-risk/high-reward project.

Reviewer 2:

The reviewer acknowledged that intermetallics present an entirely new list of headaches with regard to both manufacturing and durability, but the potential performance aspects and light weight in the rotating assembly make it worth pursuing thoughtful research. The reviewer noted that the extensive use of computational tools also indirectly supports DOE program goals on how to shape program efforts. It is good to see some DOE programs focused more on fundamental discovery to supplement the highly applied programs.

Reviewer 3:

The reviewer remarked the project offers some long-term promise of new structural intermetallics for higher temperature applications, possibly offering good specific strength. The reviewer commented that what applications are intended is not yet clear due to a lack of information on properties targets or even existing properties.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the project is well supported.

Reviewer 2:

The reviewer found that the program is effectively leveraging the industrial partner for otherwise costly material production; the University of Florida is handling project execution using its considerable facilities and a large modeling/simulation component, which naturally translates to reasonably predictable labor costs, while the use of ORNL facilities for advanced analysis is following a cost-effective path. The reviewer noted that the project budget is neatly laid out.

Reviewer 3:

The reviewer responded insufficient and referenced comments made under Proposed Future Research. This comment is not a reflection on the investigators or their plans, but a notation that the team may need additional resources or partners if these three comments are explored. The reviewer clarified that these comments are not explored, the reviewer’s response would change to “sufficient.”

Presentation Number: mat101
Presentation Title: Integrated Computational Materials Engineering (ICME) Development of Carbon Fiber Composites for Lightweight Vehicles
Principal Investigator: Xuming Su (Ford)

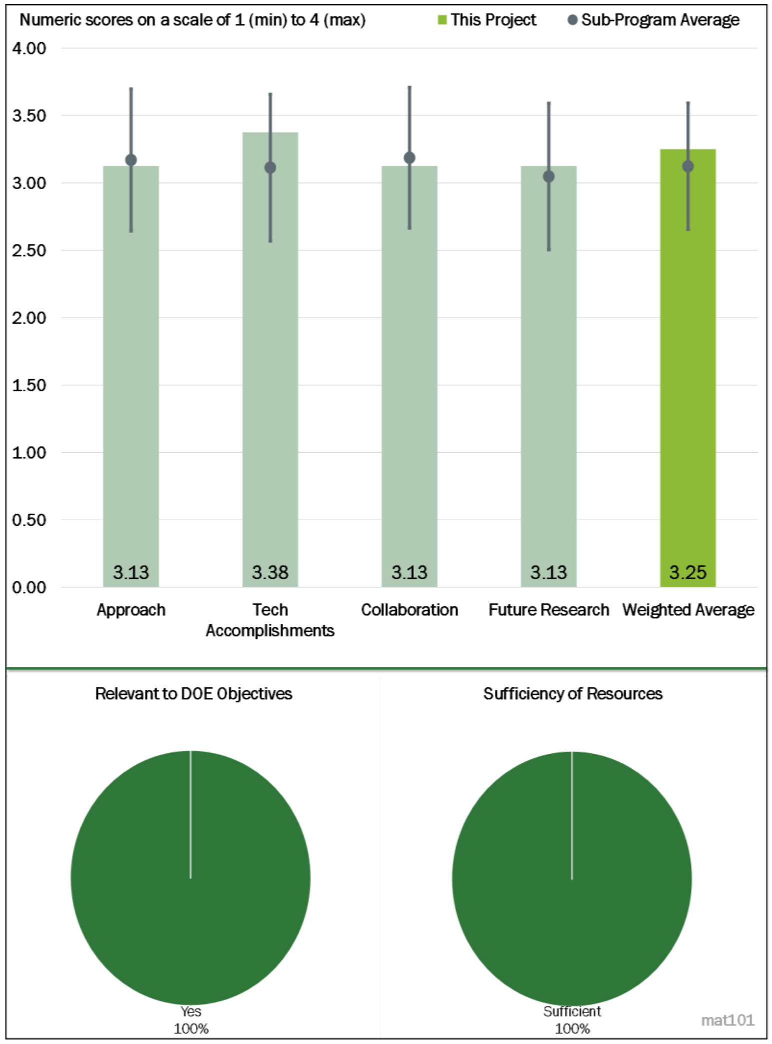

Figure 6-6 - Presentation Number: mat101 Presentation Title: Integrated Computational Materials Engineering (ICME) Development of Carbon Fiber Composites for Lightweight Vehicles Principal Investigator: Xuming Su (Ford)

Presenter
David Wagner, Ford

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer found that the approach is well-designed and much accomplishment has taken place with three different material sets. The presentation noted that sheet molding compound (SMC) was the most challenging in prediction. It is known that some of the modeling tools that exist still have additional work that needs to be done on them to better predict the fiber orientation, which may been the cause of the accuracy of the prediction.

Reviewer 2:
The reviewer noted an excellent summary of a broad range of topics. What was particularly interesting for the reviewer was SMC flow modelling and the size of models and computing time required for satisfactory results. The reviewer said the project must address a “reduced” modelling approach to make such simulations palatable.

Reviewer 3:
The reviewer remarked that the effect of sizing of the CFs will have significant impact on the dynamic (crashworthiness) properties. The reviewer inquired to what extent has the modeling effort captured this, and how will the results influence the design/decision making in adopting the CFCs in this application.

Reviewer 4:
The reviewer remarked that mold flow was used at a small plaque level, which cannot be extrapolated to large three-dimensional (3-D) parts.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer noted that some good results have been reported.

Reviewer 2:
According to this reviewer, the breadth of activity and the reported results speak highly of the technical team and their accomplishments. Predictive tools for fatigue life in nCode is an important result. The reviewer suggested that extending the constant life diagrams of the UD laminates (0 and 90) as a predictive tool for a generalized off-axis laminate should be addressed and would represent an important expansion of capability. Similarly, this reviewer applauded the progress made in the application of mode I and mode II strain energy release rates for progressive failure analysis in dynamic/transient response (crash) and integrating cohesive elements in the crash modelling.

The reviewer would like to ask for additional clarity on the author’s experience on using these tools for modelling mixed mode loading/failures.

The reviewer cited impressive progress made on probabilistic methods and use across the micro- and meso-scale level. The creation of a parametric representative volume element (RVE) library is an important component to accurate predictive methods. The reviewer said that it would be very helpful to demonstrate the use of these tools in prediction of additional arbitrary material/ply properties of new material systems/combinations of resins and fibers.

Reviewer 3:
The reviewer acknowledged that the project has done a lot of work, but the one thing this reviewer was struggling with was the take-away message on the accomplishments. There were several accomplishments, but the reviewer had to dig and look for them in the presentation and the reviewer did not think the message was clear on what accomplishments were against the performance metrics.

The other detail that was unclear to this reviewer is how the connection between each modeling step connected with the next and how it influenced the prediction of that step. According to the reviewer, the uncertainty propagation was not clear on how the information helped provide better predictive properties with the initial inputs providing predictive end goal outputs before tooling and molding would be committed.

Reviewer 4:
The reviewer said that integrating several software to address the complex multi-scale constituent materials and their interactions are well captured in the project. The reviewer said that additional emphasis on interface will help provide additional insight into the failure mechanisms.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer remarked that the Ford collaboration with Dow, industry partners, and the academic partners is excellent, and each partner has a demonstrated role in the project.

Reviewer 2:
The reviewer remarked that team members are solid.

Reviewer 3:
The reviewer said that from the looks of the overall progress of the project, the team had good collaboration, but the reviewer was unclear during the presentation which collaborators did which part of the work. The reviewer found the slide on the team responsibilities and the coordination was helpful.

Reviewer 4:
The reviewer noted that while the presenter briefly discussed the collaboration and partners, it was not clear where each collaborator contributed during each presented phase. The reviewer observed a well-coordinated team and suspected the collaboration was effective, just not the thrust of the presenter's prepared slides.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked the project is ending, and with excellent work on a complex problem.

Reviewer 2:
The reviewer said that the program is nearing completion and with six months remaining, the project team has outlined specific activities in the complete range of ICME technologies. The reviewer suggested that it would be helpful to define/tabulate the specific elements of each (for example, what remaining material characterization tests will be completed on the woven composite fabrics?) and how ICME will be used to predict these values, etc. Similarly, the reviewer inquired what subsystem and crash environment is planned for the simulation, and asked if this is planned to be accomplished on a previously tested part to compare analysis with a physical test.

Reviewer 3:
The reviewer found that the projected work to be done between now (July to end of December 2018) seems very ambitious. The team is looking to perform RVE, crash, uncertainty, design and optimization within the balance of the project. The reviewer was unclear how in-depth work can be done in all these areas within the given time constraint.

Reviewer 4:
The reviewer commented the drawbacks will be addressed.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer found that this program is a fine example of technologies necessary to meet DOE's lightweighting goals for 2030. The development and application of ICME tools for the predictive performance of reinforced polymers is absolutely imperative for the future use of these materials in commercial automotive applications. The reviewer remarked that a focus on cost modelling to generate a positive value proposition for weight reduction is similarly imperative. The author has done a very good job in motivating this research.

Reviewer 2:
The reviewer noted that a good theoretical understanding of the behavior of composites is a must.

Reviewer 3:
The reviewer noted that the project helps speed up the implementation of CFCs through utilizing computer-aided engineering (CAE) capability that will help evaluate the benefits prior to moving to expensive tooling and molding.

Reviewer 4:
The reviewer commented that the work focuses on lightweighting, modeling, and prediction for design into future vehicles. These technologies are within relevance to DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
According to the reviewer, the presenter has clearly shown specific accomplishments that meet milestones and achieve the goals stated in the program. This reviewer would simply like to see these results applied to a full-scale component along with comparison of physical results to predictions (material, structure, test and cost). The reviewer remarked resources necessary to achieve this are clearly not available for this effort.

Reviewer 2:
The reviewer said there is enough funding to deliver the stated goals.

Reviewer 3:
The reviewer commented sufficient resources were allocated for this project and milestones were completed in a timely manner.

Reviewer 4:
The reviewer said the project has adequate resources based on partners and collaborators.

Presentation Number: mat113
Presentation Title: Magnesium Corrosion Characterization and Prevention
Principal Investigator: Mike Brady (Oak Ridge National Laboratory)

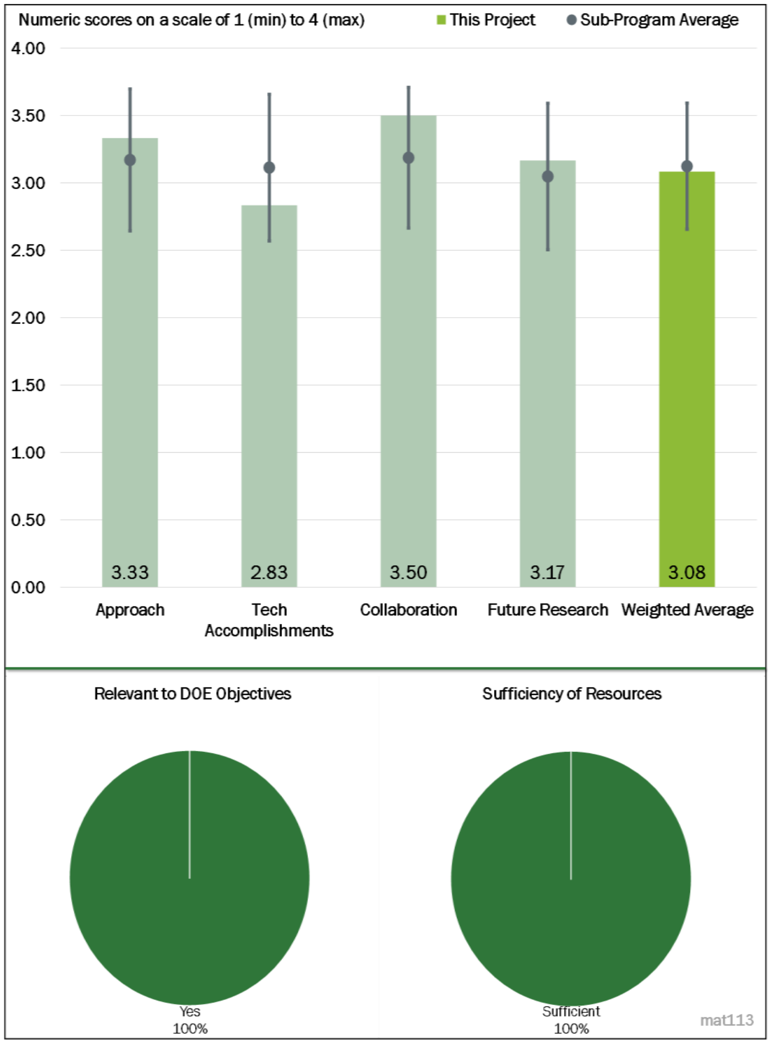

Figure 6-7 - Presentation Number: mat113 Presentation Title: Magnesium Corrosion Characterization and Prevention Principal Investigator: Mike Brady (Oak Ridge National Laboratory)

Presenter

Donovan Leonard, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the presentation did not completely explain an approach to the work, but no clear gaps can be identified. Seems like a reasonable experimental approach to generate data on corrosion behavior.

Reviewer 2:

The reviewer said that the research shows significant advancements in preventing Mg corrosion and the fundamentals of corrosion science. The researchers produced great results for the effects of various elements on surface coatings and coating thicknesses for electro-ceramic and electro-chemical coatings. The reviewer remarked the research findings on how E-coats percolate into the layers of electro-ceramic coatings and migration of Al from the alloy into the electroceramic coating were very good. The remaining studies should address the shortcomings and optimization of the coating layers.

Reviewer 3:

The reviewer noted that the corrosion performance of Mg alloys is being assessed using potentiodynamic and immersion techniques. The results indicate less of a corrosion attack on coated samples; the potential did not change after immersion. The characterization is carried out using various microscopial and electron beam instruments. The reviewer commented that this work will reveal more fundamental nature of corrosion including interfaces, coatings and diffusion of elements. The project is fundamental research and more work needs to be carried out to find evidence from older work that was carried out.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer detailed that the focus of the work is on characterizing corrosion processes using various microscopical technologies; however, the observations need to be compared with earlier work or where characterization was carried out using other instruments. The reviewer observed that the coatings selected seem to be adequate for static corrosion resistance as revealed by immersion tests.

Reviewer 2:

The reviewer remarked there seems to be a great deal of characterization that is in progress or yet to be analyzed for a project that ends in 3 months. While the reviewer appreciated the challenges with the series of continuing resolutions, it seemed like there was some more information in the back-up slides that was not discussed at all.

Reviewer 3:

The reviewer noted that the project is 70% complete and a large amount of scientific information has been gathered on the nature of various electro-chemical/ceramic coatings on Mg in just a couple of years. Although fiscal year (FY) 2018 funding was delayed, the project demonstrated good progress toward the coating characterization and obtaining in situ and ex situ data.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the project demonstrates outstanding collaboration between a national laboratory, various universities, a Mg manufacturer, and two Tier 1 materials suppliers. The expectation is that the Tier 1 suppliers will promote the findings of this research to the automobile OEMs.

Reviewer 2:

The reviewer thought it seemed that ORNL is doing the heavy lifting on this project; the wider manufacturing buy-in was not as clear.

Reviewer 3:

The reviewer observed that an international team is conducting the research, and the activities are coordinated. According to the reviewer, the relevance of the work is proved by the direct involvement on the coating selection and testing by the industry partners.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer observed that although this project will be ending in the next few months, the PIs are planning to finish the data analysis and other programmed experiments and tests within the given timeframe. The presentation indicates that "multiple" technical papers will disseminate the findings of the research, which is good for completion of the project.

Reviewer 2:

The reviewer referenced prior comments. There seems a lot to do in the next 3 months, particularly if that includes analysis and writing. There certainly seems to be a lot of good characterization work, but it is not clear to this reviewer if that will necessarily lead to a conclusion on the cause of the different corrosion behavior. The reviewer urged the investigators to consider "good practice," "lessons learned," and/or “methods” papers. Development of a standard practice for evaluation of corrosion in Mg seems to be an unmet need.

Reviewer 3:

The reviewer noted that future work consists of continuation of the current characterization. However, more knowledge could be gained by comparing the results with that available from past literature.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer noted how corrosion of Mg is a significant barrier to use.

Reviewer 2:

The reviewer detailed that one of DOE’s objectives is to improve the fuel efficiency of automobiles through using lightweight materials. When lightweight materials, such as Mg, are joined to other lightweight materials, the probability of some type of corrosion is high. The reviewer cited that the work done in this project helps better understand the corrosion mechanisms and the effects of industrial coatings to prevent it, thus providing a means of joining these materials in lightweight vehicles.

Reviewer 3:

The reviewer noted how corrosion is the most important problem for Mg alloy development. Understanding the mechanisms of corrosion, including diffusion of elements, hydrogen evolution, coating adhesion, and interface stability, will provide a basis for better coatings and durability. This work is providing the base by conducting characterization using most novel techniques. However, the reviewer pointed out that results need to be supported by other work.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted this 3-year project is funded at $1.15 million by DOE, or about $400,000 per year. This amount is typically sufficient for the research being conducted by the various collaborators, primarily a national laboratory and a few universities.

Reviewer 2:

The reviewer said that this project needs additional resources in the future.

Reviewer 3:

The reviewer had no comments.

Presentation Number: mat117
Presentation Title: Development and Integration of Predictive Models for Manufacturing and Structural Performance of Carbon Fiber Composites in Automotive Applications
Principal Investigator: Venkat Aitharaju (General Motors)

Presenter

Venkat Aitharaju, General Motors

Reviewer Sample Size

A total of four reviewers evaluated this project.

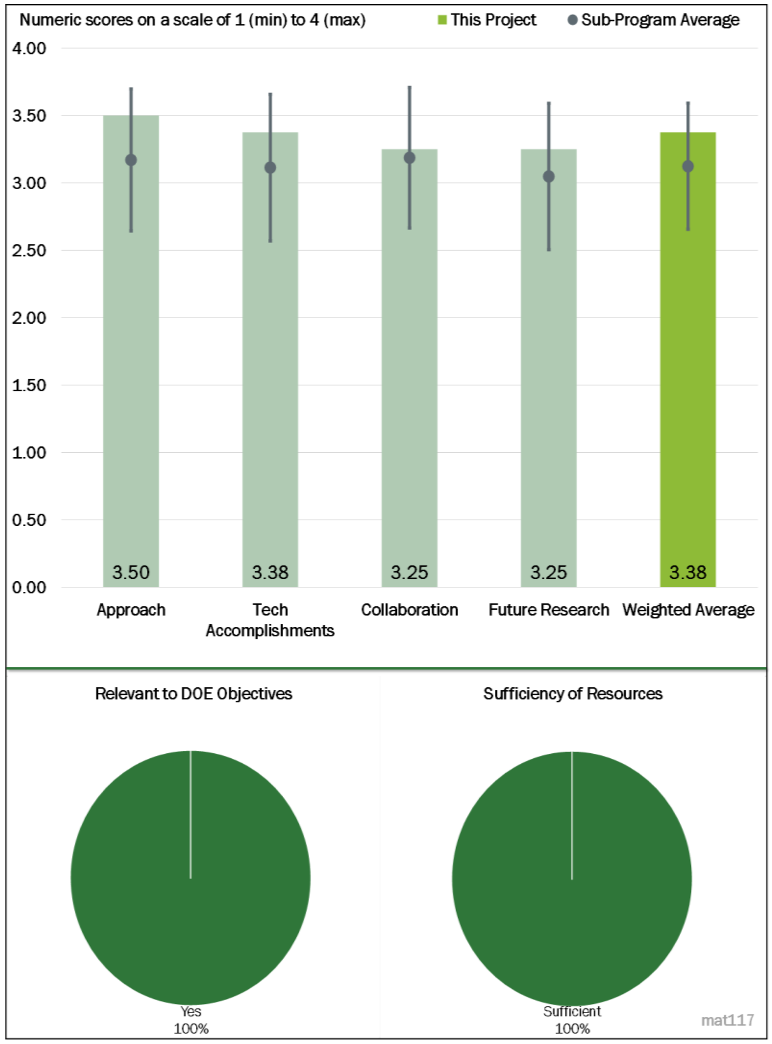

Figure 6-8 - Presentation Number: mat117 Presentation Title: Development and Integration of Predictive Models for Manufacturing and Structural Performance of Carbon Fiber Composites in Automotive Applications Principal Investigator: Venkat Aitharaju (General Motors)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the approach to this complex problem is very well thought-out.

Reviewer 2:

The reviewer remarked that the approach to performing the work was very well laid-out and the team collaboration was clearly stated at the beginning of the presentation on the roles of each participant.

Reviewer 3:

The reviewer remarked the author has provided a useful flow diagram of the approach for the application of stochasitic methods in material property prediction and manufacturing. This reviewer would like to have seen more detail related to the generation of the probabilistic distribution functions that make up the inputs for both material performance and manufacturing variation to assess the likely ability to capture the full range of physics. From the variations of RVE to variance in fiber strength (Weibull), modulus, and defect density and type on the fiber, the opportunities to generate and apply multiple parameters in the pair distribution function (PDF) is rich. The author did a good job of describing, but more difficult to understand the implementation and the means of creating the PDF for each variable. The reviewer found that nonetheless, the approach is solid and will likely yield useful results that will be applicable to physical problems.

Reviewer 4:

The reviewer stated that the work progress is excellent, and the team has addressed the technical barriers in terms of manufacturing technology and stochastic materials and manufacturing simulation tools, in aiming to meet the cost metric. In general, the reviewer found that the project demonstrated feasibility, but it was unclear how the resin transfer molding (RTM) experiments translate to high-pressure RTM (HP-RTM) where the injection pressures exceed 1500 psi and over. While fast-curing resin simulation was addressed to a limited extent, the reviewer inquired how the draping characteristics influence micro-permeability, material wash, and related changes in fabric movement at high pressures.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer remarked the project is on track with all milestones being met.

Reviewer 2:
The reviewer observed excellent work on demonstrating the prediction with experimental. It would be beneficial in the future to demonstrate the progress with the percentage of correlation between predicted and experimental.

Reviewer 3:
The reviewer said that acceptable progress has been shown in both the application of stochastic methods of analysis for material/structural and manufacturing modelling. The example of a truncated pyramid to capture and model the multi-variant elements of non-crimp fabrics (NCF) draping, mold filling, cure, and resulting mechanical properties captures a tremendous breadth of activities. The reviewer observed that the presentation of methods and approaches to capture physical behavior of NCFs was comprehensive, but the reviewer was not entirely clear on the means of tying this to variance, what might be observed in stitch type, density, or other physical parameters that impacts draping. This reviewer would like to have seen more behind the means to determine the input PDF’s that constituted the modelling and the methods of solution applied, but assuming these are well-documented and ready to be integrated within a design environment, the progress is solid.

Reviewer 4:
The reviewer referenced prior comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer observed a well-constructed team thoughtfully assembled to include an OEM, Tier 1, and analytical support from both industry and academia. The roles of the collaborators are well-defined and the presenter referred frequently to the contributors and participants of any given activity. The reviewer exclaimed well done.

Reviewer 2:
The reviewer commented collaboration between GM, Continental Structural Plastics, ESI Group, Altair, and the University of Southern California seems to have a defined role for each partner and seems to have worked efficiently in this program.

Reviewer 3:
The reviewer commented collaborations between an OEM, other entities, and universities are excellent. The reviewer pointed out that there is no national laboratory partner, however.

Reviewer 4:
The reviewer said even though the results of the work show great progress and the team collaboration was clear on the roles in the project, the reviewer was unclear how the project was coordinated with all of the participants.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked future research is well aligned with the rest of the project.

Reviewer 2:

The reviewer observed excellent next steps for validating the models with tooling and molding to demonstrate the accuracy of the model with scaled-up experimental data.

Reviewer 3:

The reviewer commented that the team has made sufficient technical progress and demonstrated high fidelity in predictive modelling and specifically in applying the stochastic methods to warrant a move to complete a full-scale automotive assembly. The reviewer pointed out that proposed future work is an important element of demonstrating applicability and practicality in prediction of manufacturing, performance, and cost of CFRP structures. This reviewer is simply disappointed that a specific component has not been identified and presented for consideration. This omission simply makes it difficult to provide a complete assessment into the quality and completeness of planning for future proposed work. Particularly, an assessment of resource requirements and applicability. The reviewer asked if a component is not fully identified at this stage of 2018, how can a design and fully completed tool package be fabricated by the end of this year.

Reviewer 4:

The reviewer said that, in general, the proposed future research is reasonable, and that the work to be done is fairly ambitious in the given timeframe. The reviewer cited as an example comparing manufacturing process predictions for the HP-RTM and compression resin transfer modeling is an expansive study given the range of differences in process conditions. The current modeling/experiments may not be directly scalable to HP-RTM. The reviewer said it was not evident from the presentation how this gap would be addressed.

The reviewer cited as an example comparing structural predictions and experimental results for the crash performance of the assembly built for demonstration. The tooling and related experiments need more definition (or at least were not evident from the presentation briefing). The reviewer also gave as an example certification of the assembly based on the ICME tools developed in the project. The reviewer noted that this is a long lead-time issue, and asked how the team addresses it to accelerate the certification process.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that the project supports the DOE goal of weight reduction utilizing improved CAE tools for predicting part mass savings based on design and materials.

Reviewer 2:

The reviewer said that this work well-supports relevance to DOE's lightweighting goals. Clearly, capturing through application of stochastic methods the well-understood variance observed in the materials and methods of manufacture is vital to successful use of these materials in a commercial automotive structure. The reviewer remarked that the author has successfully motivated this work and demonstrated relevance through successful correlation of the models to physical data generated through the program.

Reviewer 3:

The reviewer commented CF-based composites are one of the effective lightweighting strategies in the DOE Materials portfolio.

Reviewer 4:
The reviewer found that the work is directly relevant to DOE objectives in lightweighting and a multi-materials ICME approach to achieving optimized designs for future vehicles.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked that the progress and results of the work presented to date demonstrate that resources have been sufficient to meet milestones. While the work is ambitious, the presenter has clearly demonstrated the utility of the methods employed and the contribution of the collaborators appears consistent with the level of funding.

The reviewer was not clear that resources for the work remaining are sufficient. Because the author identified no specific automotive assembly, it is impossible to assess the costs required to complete the work and relevance (or value) that will result for the remaining funds available to the project.

Reviewer 2:
The reviewer remarked resources are sufficient.

Reviewer 3:
The reviewer observed excellent progress with milestones and the funding that was used.

Reviewer 4:
The reviewer said that the team is well-equipped to undertake this work.

Presentation Number: mat118
Presentation Title: Functionally Designed Ultra-Lightweight Carbon Fiber Reinforced Thermoplastic Composites Door Assembly
Principal Investigator: Srikanth Pilla (Clemson University)

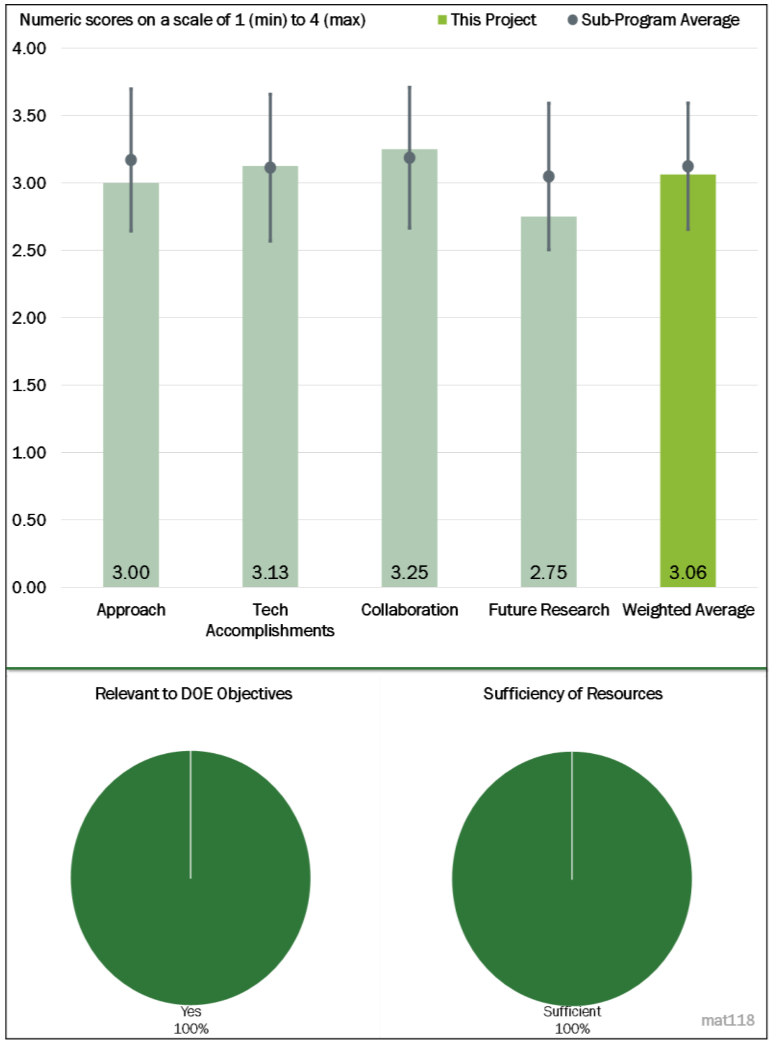

Figure 6-9 - Presentation Number: mat118 Presentation Title: Functionally Designed Ultra-Lightweight Carbon Fiber Reinforced Thermoplastic Composites Door Assembly Principal Investigator: Srikanth Pilla (Clemson University)

Presenter

Srikanth Pilla, Clemson University

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the approach to perform the work was good. As the cost of the door assembly with CFCs is one of the prime objectives, the cost models, selection of material, and manufacturing process should have worked out in the first few phases of the project.

Reviewer 2:

The reviewer acknowledged that this is a challenging problem that the Clemson team has an effective plan to address. The team is making good progress with a sound approach, but it is not clear to the reviewer that the targets will be met. The reviewer noted that the targets were stiff.

Reviewer 3:

The reviewer detailed that the project started with seven concept designs and down-selected to two. Finite element analysis was applied to each concept, and the team used optimization for gauge thickness. The reviewer found that more comprehensive optimization would be achieved by integrating material choices, functional requirements, and cost into a single CAE optimization analysis.

Reviewer 4:

The reviewer said that the project is generally on track. There are several technical barriers—particularly in that the weight optimization is done on a structural parts level—while the overall weight is impacted by the system level. Several traditional components are going to be used in the weight optimized composite structure. The reviewer recommended that an overall weight scenario including all sub-components (existing and new) should be accounted for.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked excellent progress towards meeting the targets. As noted earlier, the targets were challenging.

Reviewer 2:

The reviewer said that the project met all milestones.

Reviewer 3:

The reviewer said that it looks like the composite design meet the static requirements with mass savings of 60% compared to the baseline steel case (6.18 Kg with projected weight savings of 60%). The reviewer was unsure why the quasi-static Federal Motor Vehicle Safety Standard 214 analysis case was run with 12.2 Kg closer to steel mass of 15.45 Kg. The reviewer said the analysis should have started with 6.18 frame mass and mass needs to be increased only to meet the federal requirements rather than the baseline steel door.

Reviewer 4:

The reviewer referenced prior comments and suggested developing an understanding to capture the crashworthiness expected with the redesigned features and their interactions with respect to the traditional components such as window modules, etc. The reviewer inquired if by excessive lightweighting, these interactions will adversely influence impact performance.

The reviewer also asked what the influence is on cost metrics on multi-process design, such as thermoforming, long fiber thermoplastic and related processes and assemblies. Further, the reviewer expressed interest in the projected infrastructure to enable adoption of these designs compared to existing sheet metal processes and other thermoplastic composite options.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer observed a very good team led by Clemson and with the University of Delaware, Honda, and Corning as participants.

Reviewer 2:

The reviewer said that the partners are working closely and great progress has been made.

Reviewer 3:

The reviewer commented that the collaboration between Clemson, Delaware, Corning, and Honda seems to be going well. Each partner has a role in the project. The reviewer said the presentation identified a host of material suppliers—perhaps their roles and engagement will be more tangible in the future work.

Reviewer 4:

The reviewer noted that manufacturing of the composite door is critical for the project. The reviewer inquired if this assignment was contracted out, or if any partner is taking care of this.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the plans are well laid-out in alignment with the goals of the project.

Reviewer 2:
The reviewer remarked that there is a lot to be done in this project to assess the confidence in the design and performance. The identified pathways for dynamic simulations; manufacturing simulations and tooling design; and mass production plan and cost model refinement are all necessary to evaluate the feasibility of the downselected design.

Reviewer 3:
The reviewer stated that the proposed research works are necessary for completion of the project. A potentially better design could be achieved by an optimization that considers the impact of local variation of material properties. The local material properties are predicted by simulations of manufacturing processes, which the reviewer noted are planned future work.

Reviewer 4:
The reviewer commented that proposed future work seems very challenging in regards to dynamic simulations, and manufacturing simulations. Given these challenges, the reviewer was not sure why the proposed analysis for a plant layout is needed for this project.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer remarked that the project is a perfect example of lightweighting vehicles using composites.

Reviewer 2:
The reviewer commented the project directly supports DOE goals of lightweighting while maintaining the vehicle performance.

Reviewer 3:
The reviewer found that the relevance to DOE objectives is appropriate in terms of lighweighting and multi-material optimized design for vehicle components—an automotive door in this case.

Reviewer 4:
The reviewer said that this project support the overall DOE project objectives of automobile lightweighting and thus achieving improved fuel economy and reduced emissions.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented resources are sufficient.

Reviewer 2:
The reviewer said the team has adequate resources to conduct the work.

Reviewer 3:
The reviewer said resources seem sufficient. The reviewer pointed out the objective of the project is quite ambitious, but the project got help by involving a number of graduate students.

Reviewer 4:
The reviewer suggested that an OEM partner may be needed to provide improved support for simulations given the existing challenges in the future work.

Presentation Number: mat119
Presentation Title: Ultra-Light Hybrid Composite Door Design, Manufacturing, and Demonstration
Principal Investigator: Nate Gravelle (TPI)

Presenter

Nate Gravelle, TPI

Reviewer Sample Size

A total of three reviewers evaluated this project.

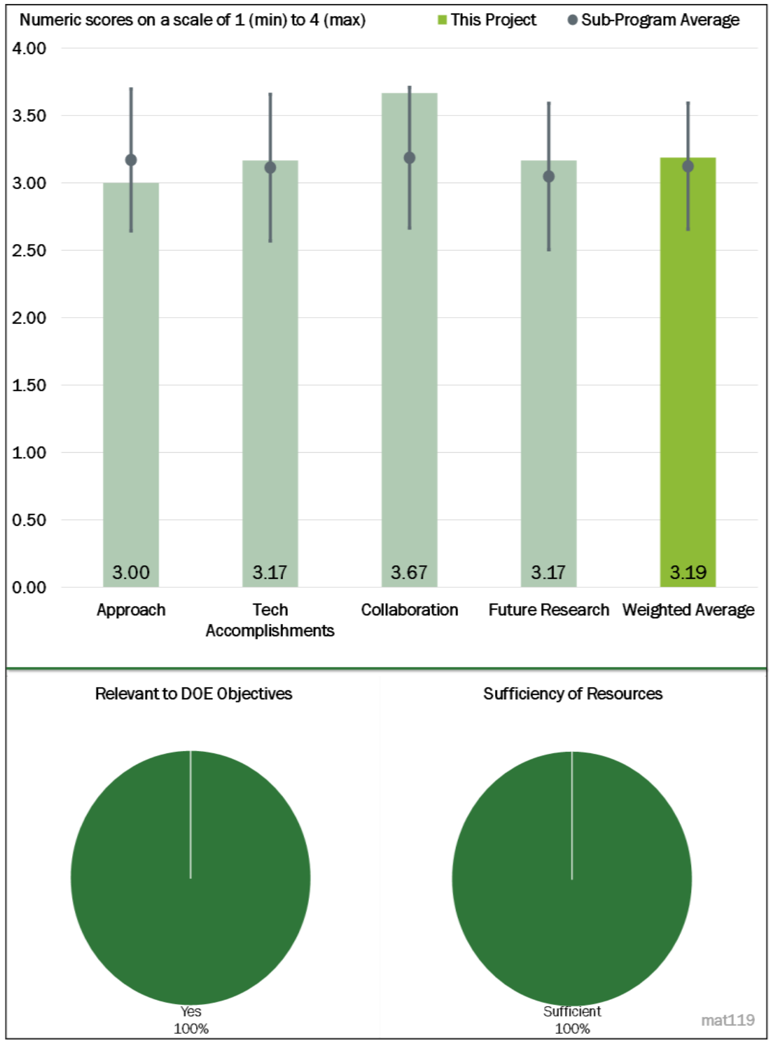

Figure 6-10 - Presentation Number: mat119 Presentation Title: Ultra-Light Hybrid Composite Door Design, Manufacturing, and Demonstration Principal Investigator: Nate Gravelle (TPI)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the overall technical barriers are being addressed very well. The reviewer was unclear how the materials were being characterized for HP-RTM where the resin is injected at 1,500 psi and above. The reviewer asked how the characterization work will translate to the HP-RTM process.

Reviewer 2:

The reviewer remarked this presentation says little about the approach, and there is little information on the molding process, the subcomponent fabrication, or the subcomponent evaluation. The reviewer remarked that there are few details about the CAE analysis; the local material properties, for example, are completely missing from this presentation. There is a picture of dynamic CAE for side pole impact, but no information. The reviewer noted that while there was a go/no-go gate in October 2017 based on the demo manufacturing rate, there is zero information in this review presentation. The reviewer said there is no discussion of the critical performance measures for the design. The reviewer had expected to see metrics or targets for stiffness, strength, impact, fatigue, corrosion, sealing, noise transmission, appearance/smoothness, dent and ding resistance, palm dimpling/oil canning, and door closing sound quality. The reviewer said that none of these performance requirements are addressed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that some input was included in Q.2.

Reviewer 2:

The reviewer said that there is little information on the technical accomplishments other than the CAE design. The reviewer was unclear if the load case of dent and ding damage to the outer panel was addressed in the CAE. The lack of information on the material properties is disappointing. The reviewer said there is little information on the materials or the processing conditions. The reviewer was perplexed that the design fails to meet the torsional rigidity requirement, yet is deemed okay. This reviewer expected to see information on the manufacturing process to yield the cycle time that is stated to be a major objective of the project. Additionally, there is little information on the testing to prove the design and correlate the CAE. With the failure to meet torsional stiffness, the reviewer expected failures in the wind, noise, and water leak tests for this design. Also, the Class A surface finish is a requirement for the door, and the reviewer said that this project ignores this performance requirement.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the collaborating team of TPI Composites with Hexion, Saertex, Creative Foam, Alpex, Krauss Maffei, and the University of Delaware is excellent.

Reviewer 2:

The reviewer stated that while the listed subcontractors are appropriate for this project, the collaboration and cooperation are not clearly defined. For next year, the reviewer recommended that the project please include a matrix of when different groups meet and cooperate on aspects of the project. The reviewer acknowledged this is likely okay, but there is little evidence in the presentation.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that the future work in terms of tool build, crash modeling of the intrusion beam, and using low-cost CF are appropriate and much-needed for the next steps.

Reviewer 2:

The reviewer said that because no design verification tests are defined, it is difficult to comment on the proposed future work. The reviewer would have expected to see the full verification test plan at this point in the project. Hopefully, there will be full vehicle testing for water leaks, wind noise, corrosion, moving barrier side impact, and side pole impact. The reviewer said that hopefully, there will be component testing for dent and ding, palm loading as well as slam durability, overload open, and other component tests. The reviewer said that future work stated on Slides 22-25 appear vague. The reviewer inquired what the project team will do to reduce the mass of the door internals that comprise more than half the door mass.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that the project addresses the cost and weight reduction metrics through materials and process innovations.

Reviewer 2:

The reviewer remarked this projects supports the DOE goals of vehicle mass reduction and increased use of CFC materials.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked a total of $5.9 million are sufficient resources to produce and test a prototype side door. The time is sufficient to complete the design, tooling, manufacturing, assembly, and testing for a driver's door.

Reviewer 2:

The reviewer commented that the team has excellent resources.

Presentation Number: mat122
Presentation Title: Low-Cost Carbon Fiber Research Using Close Proximity Electromagnetic Carbonization (CPEC)
Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

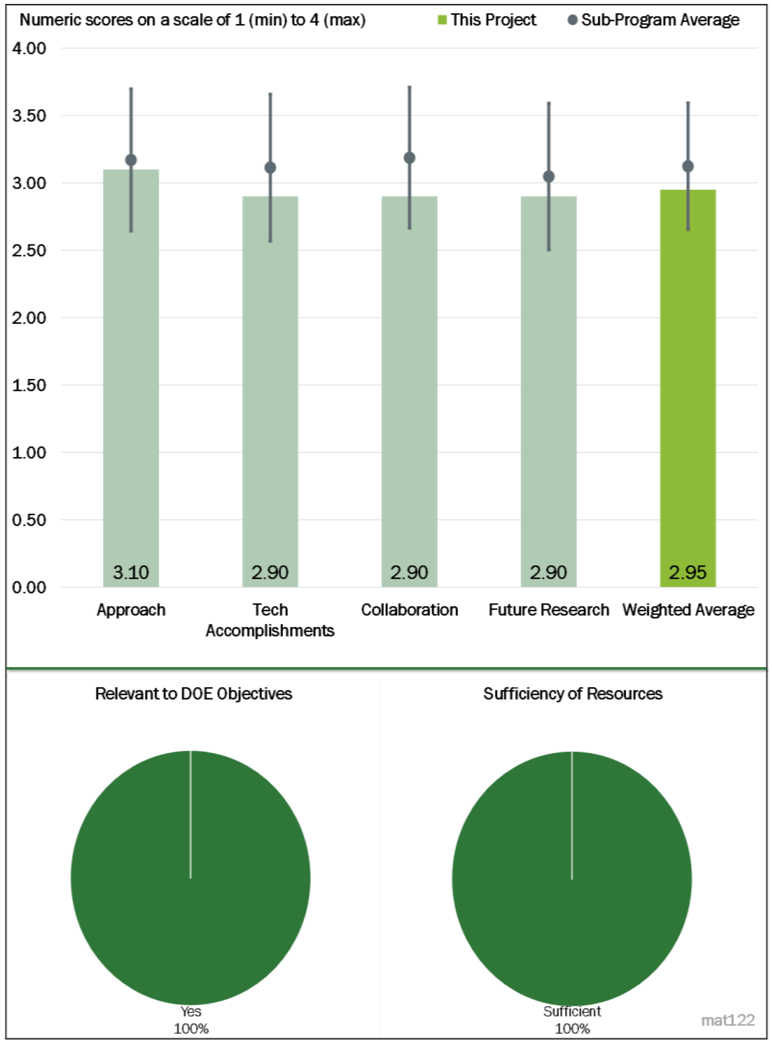

Figure 6-11 - Presentation Number: mat122 Presentation Title: Low-Cost Carbon Fiber Research Using Close Proximity Electromagnetic Carbonization (CPEC) Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

Presenter

Felix Paulauskas, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that this is an excellent project. The approach is sound with dielectric heating to heat the fiber rather than the gas surrounding the fiber. This should reduce the energy required and hence reduce the cost.

Reviewer 2:

The reviewer commented that it is important to reduce energy consumption

Reviewer 3:

The reviewer stated that the project has made good headway in its goal to reduce unit energy consumption of low-temperature carbonization (LTC) stage (kWh/kg) by approximately 50% or 5% of the cost reduction on the CF overall manufacturing process. The reviewer found that the barriers are to some extent addressed—although there is a long way to go in this project.

Reviewer 4:

The idea and approach to replace thermal methods (i.e., furnaces) of LTC with methods of directed energy is important and useful. What is more concerning to this reviewer is certain assumptions related to cost and performance targets. Existing CF materials already approach the $7/lb upper cost target (at volume) suggested by the presenter. The reviewer pointed out that when this fact is combined with performance goals of 250ksi and 25 MSI (strength and modulus), the reviewer became further concerned about the research goals. Commercial/industrial polyacrylonitrile fiber today exceeds 500 KSI strength and 30 MSI modulus, making the relative value in terms of $/MSII (strength or modulus) lower than the goals set by the presenter.

The reviewer said that similarly, the goal set to reduce energy consumption by 50% in the LTC stage seems underwhelming in the total manufacturing cost model as presented by the author (i.e., 5% of total manufacturing cost). Nonetheless, a 50% reduction in any specific process is important, non-trivial and should be pursued. The reviewer is simply left wondering if the technology can be extended to other elements of CF production for greater impact.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the accomplishments from the Close Proximity Electromagnetic Carbonization (CPEC)-3 furnace are excellent. The reviewer wished the standard deviations were less. The design for CPEC-4 is complete and the procurement is underway. The reviewer said that the mix of modeling and experimental accomplishments is very strong.

Reviewer 2:

The reviewer said that the team has presented a significant amount of work accomplished, particularly in the design and fabrication of three versions of LTC prototypes. This work has demonstrated the feasibility of the technology and should also be recognized. The reviewer noted that a table of results for both fiber strength and modulus was presented and partial victory was claimed regarding programmatic goals; however, scatter in the strength results of even the most promising trial was so high as to yield unusable materials in a practical application. It is not clear to this reviewer why the technical leader would progress to scaling the process (i.e., build CPEC-4) without fully identifying and mitigating the sources of this variation and demonstrating a significant reduction in fiber variation.

The reviewer also pointed out that there was no data presented regarding energy requirements for the LTC and thus no direct correlation to the most important goal, identifying opportunities for both cost and energy reduction. The project goals and relevance will be significantly enhanced by incorporating a comprehensive cost model to reflect increase in line capacity from shorter residence time as well as the impact on energy reduction and change in CAPEX expected. The reviewer asked how these factors will affect total cost. It would be helpful for the project team to expound on the use of computer aided design and the usefulness of the results to improve the design of the CPEC-4. The reviewer was not clear how the modelling is used in the machine or process design.

Reviewer 3:

The reviewer commented that more work is needed to improve mechanical properties and reduce scatter.

Reviewer 4:

The reviewer remarked that the infrastructure to scale-up this process and energy implications of scaling up for the electromagnetic (EM) field was not clear. The reviewer asked how the cost metric will be influenced by scaling up the EM generators. The reviewer asked how attractive this process will be when alternate processes are providing fiber in the 350-400 ksi and 35+ Msi range, and will the EM process be less expensive than thermal processes to obtain low-cost CF.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that ORNL collaboration with RMX Technologies, 4M Carbon Fiber Corp., and Litzler is very good and each partner has a specific role.

Reviewer 2:

According to the reviewer, the team is focused on this targeted effort for carbonization. The plasma experts, the oven manufacturer, and a CF supplier are the proper team for this project. The reviewer suggested showing the frequency of Web-based meetings and face-to-face meetings to clearly describe the collaborations.

Reviewer 3:
The reviewer said that industrial partners appear adequate to support this project. More discussion regarding the scaling of the equipment and the involvement of the collaborators meeting certain CAPEX and capacity requirements for commercialization would be helpful to assess the probability of success. The reviewer said that the author did not provide detail regarding the contribution of each participant in the different phases of technical progress.

Reviewer 4:
The reviewer noted that ORNL has the major role.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer pointed out that a lot of the proposed research hinges on the CPEC-4 furnace build and optimization—this will provide the investigators all the data for their next steps. The reviewer found that this is a reasonable goal.

Reviewer 2:
The reviewer found that the future work proposal is clear and concise. What remains missing is the technical means to overcome the variance seen in mechanical strength and the challenges associated with scaling from a single tow to multi-tow LTC processing. The reviewer remarked that the author has not provided any detail regarding the baseline throughput or energy requirements for conventional furnace processing of the LTC stage of carbonization. It would be helpful to outline the details of measurement and comparison. The reviewer said that it would also be helpful for the author to present or outline the steps of economic evaluation. The reviewer asked what the baseline assumptions and costs are.

Reviewer 3:
The reviewer commented that the future work addresses all the challenges now foreseen in the project. The scale-up will likely produce other, currently unforeseen challenges the team will address. The reviewer recommended that the controls to tune the electric field to carbonize the fiber and thus reduce the standard deviation of the final properties must be addressed.

Reviewer 4:
The reviewer commented to address the shortcomings of the current results.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that CF cost reduction is very important.

Reviewer 2:
The reviewer said that this project addresses the cost of CF by focusing efforts on reducing the energy for the carbonization.

Reviewer 3:
The reviewer commented that the current project supports the overall goal to expand the use of lightweighting materials by 2030 through a reduction in the fundamental cost and embodied energy in CF manufacturing. The reviewer pointed out that the only question is whether the funds expended are returned through the economic impact, which has not been fully qualified. That is the most significant flaw contained in this project.

Reviewer 4:

The reviewer noted that the project deals with alternate ways of producing CF and may have an impact on the U.S. manufacturing base provided the team is successful in lowering cost at the relevant scale.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said the funding is sufficient.

Reviewer 2:

The reviewer said that the team has adequate resources and expertise to carry out the work.

Reviewer 3:

The reviewer said that resources are sufficient for the project.

Reviewer 4:

The reviewer remarked that there appears to be sufficient funding. The specifics associated with the building of CPEC-4 makes it very difficult to assess, but the author did not express concerns regarding the costs associated with scaling the CPEC-3 and fabricating the hardware to complete the 8-tow scale-up LTC. The reviewer said that it is difficult to assess, given the lack of attention spent on modelling the economics of the process, whether resources are sufficient to complete the techno-economic modelling necessary to fully assess project impact and likelihood of commercialization.

Presentation Number: mat124
Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber for Lightweight Vehicles
Principal Investigator: Xiadong Li (University of Virginia)

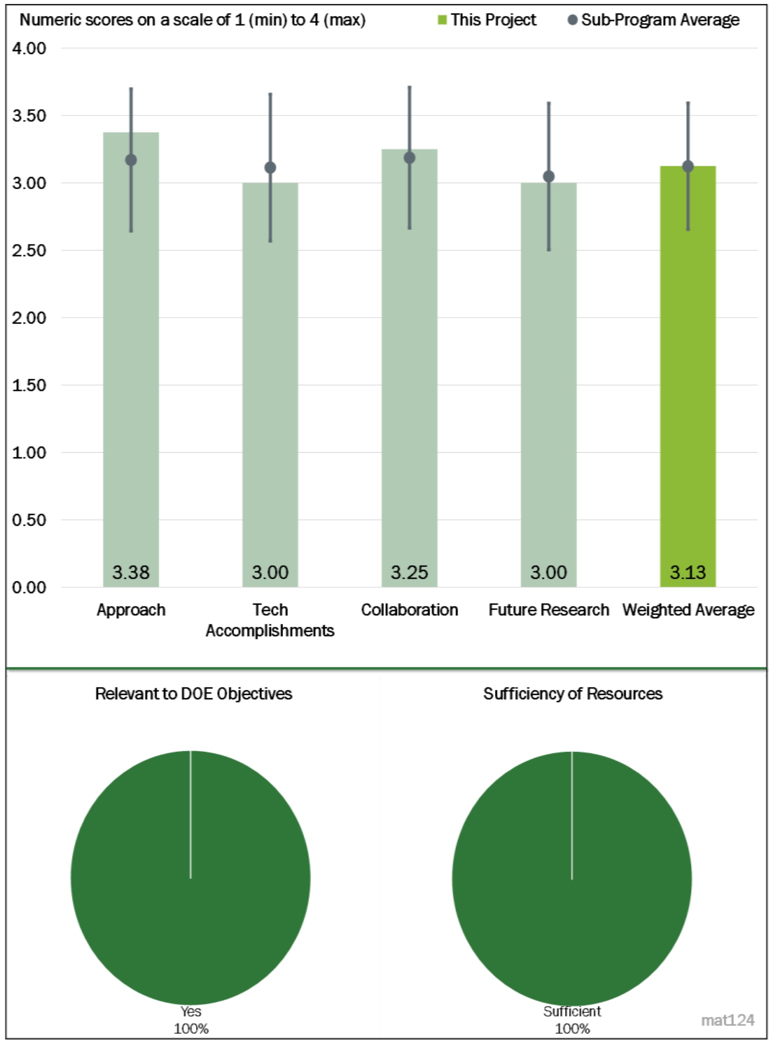

Figure 6-12 - Presentation Number: mat124 Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber for Lightweight Vehicles Principal Investigator: Xiadong Li (University of Virginia)

Presenter

Xiadong Li, University of Virginia

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the team has an attractive ICME approach to develop and deploy CF precursors with improved performance. This is an early-stage project that started this FY so the team did not have a lot to report.

Reviewer 2:

The reviewer said that the Approach to step through the process to see where efficiencies can be found is laudable. This should help identify opportunities for cost reductions. The reviewer said that using ICME framework to identify lower cost precursors to reduce precursor cost, and hopefully reduce the energy required to produce the final CF, is appropriate. The reviewer identified as one issue moving forward the inhetrogeneity of the precursor. This is what doomed previous efforts on lignin precursors. Within the research, the reviewer stressed that care must be taken to quantify the amount of imperfections tolerated in each step of the process.

Reviewer 3:

The reviewer said that the approach outlined in the reviewed presentation lacks specificity regarding the modelling and simulation methods as well as the specific testing proposed. The back-up slides expose a bit more detail, but relatively important elements related to embedded flaws in the atomic structure and whether stochastic in nature or a result of precursor chemical makeup and contamination would (notionally) appear to be an important consideration to bake into a model/simulation.

The reviewer remarked given that cost is such an important element (or constraint) in determining project success or failure, there is a general lack of attention to modelling, or including in the framework the fundamental elements of cost modelling. This reviewer would like to see, at the very least, identification of the cost elements and the methods this research will use to model these costs in parallel to modelling the performance. The reviewer noted how the team pointed out the challenge of costing given the chasm between lab scale an industrial scale, but according to the reviewer that is not suitable justification for not addressing the specifics of a cost model.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer pointed out that this is an early stage project as mentioned so the team has limited progress at this time.

Reviewer 2:

The reviewer remarked the initial Technical Accomplishments are promising and on track. In the molecular dynamics work, the reviewer hoped that the researchers include imperfections in the precursor and propagate the effects of those imperfections throughout the analyses. The reviewer commented he initial work only addresses “perfect” chemistry.

Reviewer 3:

This reviewer is concerned that specific technical progress related to the milestones is thin. Little was presented either in the experimental or simulation efforts that will be required to meet Milestone 2 and Milestone 3. The reviewer said it would be helpful to have been exposed to some of the specific modelling approaches used and the chemistry assumed in setting up the simulation. The reviewer thought it would be much easier to assess the progress and the likelihood of success for these two milestones. Additionally, Milestone 4, while referenced to be 80% complete, lacked detail in terms of reporting on the methods used to optimize wet/melt spinning processes and the results of this optimization.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that this is a strong team led by a university, but with additional national laboratory and industry members as part of the team.

Reviewer 2:

The reviewer said that this is a well-thought out project team with adequately identified roles. The reviewer would like to better understand the role of Oshkosh, particularly in supporting the requirements, testing, and application of the results. Their understanding of product cost versus performance would appear to be critical for establishing metrics for success.

The reviewer noted that the presentation did not identify or present specifics regarding rhythm or team interaction, meeting, teleconferences, and quarterly reviews. This would be helpful to include given the breadth of the project team and the roles each must play.

Reviewer 3:

The reviewer remarked that monthly meetings are barely enough to keep this complex project running smoothly. Especially during this critical first year, the reviewer recommended that the group needs more frequent contact to form up as a high functioning team. The reviewer encouraged weekly web-based meetings and monthly face-to-face meetings for the next year.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that there is scarce detail related to work planned for the balance of this FY or the two remaining. Given the large resources provided by the federal government ($3 million), this reviewer would expect more detail regarding the direction of the work plan. Particularly, given the overarching goal of developing models and simulations that will lead to the use of fundamentally lower-cost precursors to yield CF products below $5/lb. The reviewer asked what additional equipment requirements will be put in place, if any, to work on conversion of new precursors. The reviewer also asked what screening the team might use to determine the potential for alternative precursors to meet cost performance, mechanical performance, and scalability.

Reviewer 2:

The reviewer cited a couple of questions to ask. The reviewer asked if models for oxidation/carbonization, etc., are equally difficult/easy. The reviewer said that some sort of gap analysis will be useful to go with this ICME project. The reviewer cited that the team used ReaxFF simulations to quantify bond energies. The reviewer asked if it is clear that benefits at the bond level translate to the fiber level and if so, is there literature supporting that.

Reviewer 3:

The reviewer remarked that proposed future work is appropriate. However, the description in the presentation is rather vague on what “alternative precursors” will be considered. The reviewer noted that Technical Accomplishments showcased “Exploration of alternative precursors and production methods;” however, no specific information was given other than nylon will be investigated.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said that efforts to investigate alternative precursors and all the processing steps are key to reducing the cost of producing CF.

Reviewer 2:

The reviewer pointed out that CF-based composites is one of the key areas in the lightweight materials portfolio.

Reviewer 3:

The reviewer remarked that the drive toward lightweighting (as well as all the benefits gained from non-metallic solutions for automotive and transportation systems) is predicated upon creating fundamentally low-cost, high specific property materials. In particular, CF has a fundamentally low-cost atomic make-up (C...pretty common material) as well as fundamentally high specific properties (both modulus and strength) when structured properly. The reviewer remarked that this program addresses the need to develop a toolbox with which to evaluate the potential of a given precursor to meet aggressive cost and performance goals. Such capability is critical to achieve this end. The reviewer found that relevance will be positively impacted if a technically sound simulation/method of costing the scaled high-performing materials is demonstrated. The reviewer recommended there should be more emphasis placed up this component of the work.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked resources are sufficient.

Reviewer 2:

The reviewer said that the $4.4 million planned and the three-year timeline is sufficient to complete this work. While the presentation was not specific regarding equipment, computing or software required to be purchased, it is this reviewer’s belief that the financial resources are adequate for this effort.

Reviewer 3:

The reviewer said that at this point, the resources appear sufficient to complete this project in the time remaining. The access to laboratories at the University of Virginia, Penn State, ORNL, and Solvay should be sufficient to get all the work accomplished.

Presentation Number: mat125
Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber
Principal Investigator: Donald Collins (Western Research Institute)

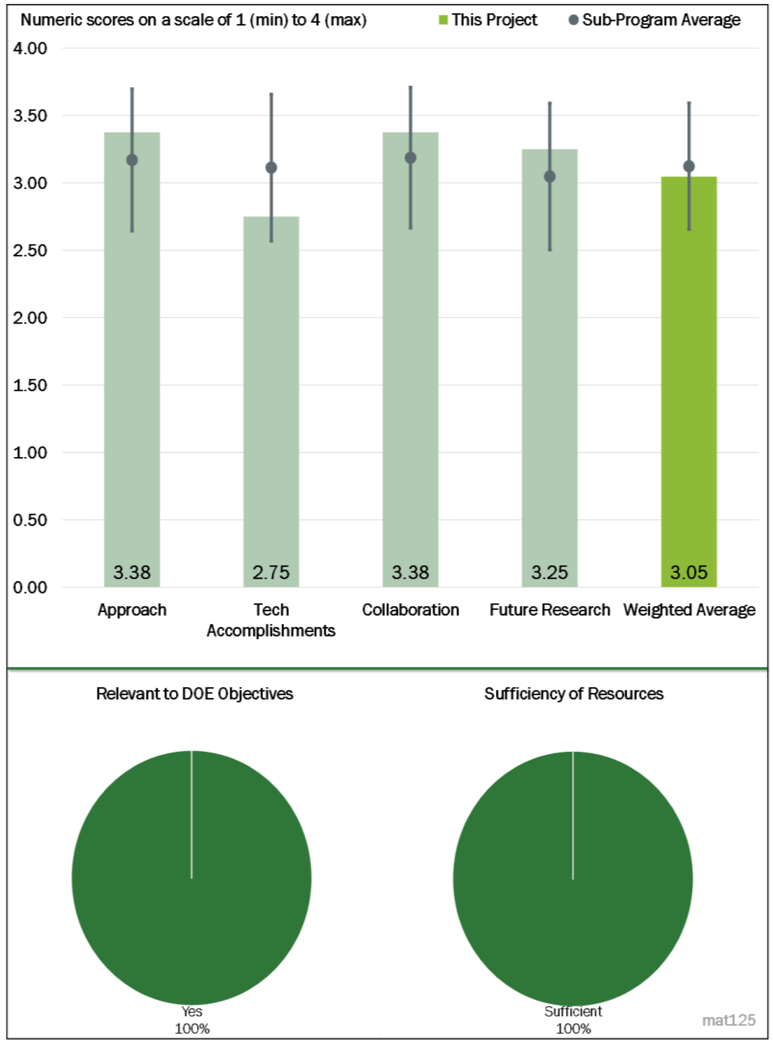

Figure 6-13 - Presentation Number: mat125 Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber Principal Investigator: Donald Collins (Western Research Institute)'

Presenter

Jeramie Adams, Western Research Institute

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed a good solid project approach for this effort. The project started this FY and the team did not have a lot to report in terms of results.

Reviewer 2:

The reviewer remarked that the Approach appears sufficient to address the project. The evaluation of multiple materials should improve the chances for low-cost CF. The reviewer recommended that the project team please play close attention to the tolerance for impurities and/or unwanted phases/defects/impurities. Also, be sure to address the mechanical (tensioning and roller controls) as well as the thermochemical processing steps.

Reviewer 3:

The reviewer recommended that feedstock heterogeneity has to be addressed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed a good start to a difficult project, and the project is poised for good progress. The details of the molecules are critical for successfully getting to CF. The reviewer noted that issues of impurities and the robustness of each process to impurities are critical.

Reviewer 2:
The reviewer pointed out that the project has just started.

Reviewer 3:
The reviewer emphasized that this is a new project so no significant technical accomplishments were provided at this time.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said good team with a number of key partners that will allow this project a good chance of success.

Reviewer 2:
The reviewer said the participants are well-positioned for this project to be successful. The reviewer suggested showing the interactions and the meeting frequency. The reviewer said that with a large, geographically separated team, the number and frequency of meetings, and particularly face-to-face meetings, is critical.

Reviewer 3:
The reviewer remarked many experts that can help.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer commented an outstanding plan for future research was well-presented.

Reviewer 2:
The reviewer remarked plans are good; the implementation has to happen

Reviewer 3:
The reviewer commented that the proposed future work is good. However, according to the reviewer, there are not sufficient details on the measurements and tracking of impurities in each of the feed streams. Also, there is no mention of the mechanical processes steps such as tensioning.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer agreed that these efforts to identify opportunities for lower-cost CFCs certainly are relevant to the DOE goals for energy reduction through vehicle lightweighting.

Reviewer 2:
The reviewer said that CF is a key material in the lightweighting portfolio.

Reviewer 3:
The reviewer noted that cost reduction and sustainability are important.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer remarked the resources appear to be sufficient for this project to be successful.

Reviewer 2:
The reviewer said that resources are sufficient

Reviewer 3:
The reviewer commented that resources are sufficient at this time.

Presentation Number: mat126
Presentation Title: Room-Temperature Stamping of High-Strength Aluminum Alloys
Principal Investigator: Aashish Rohatgi (Pacific Northwest National Laboratory)

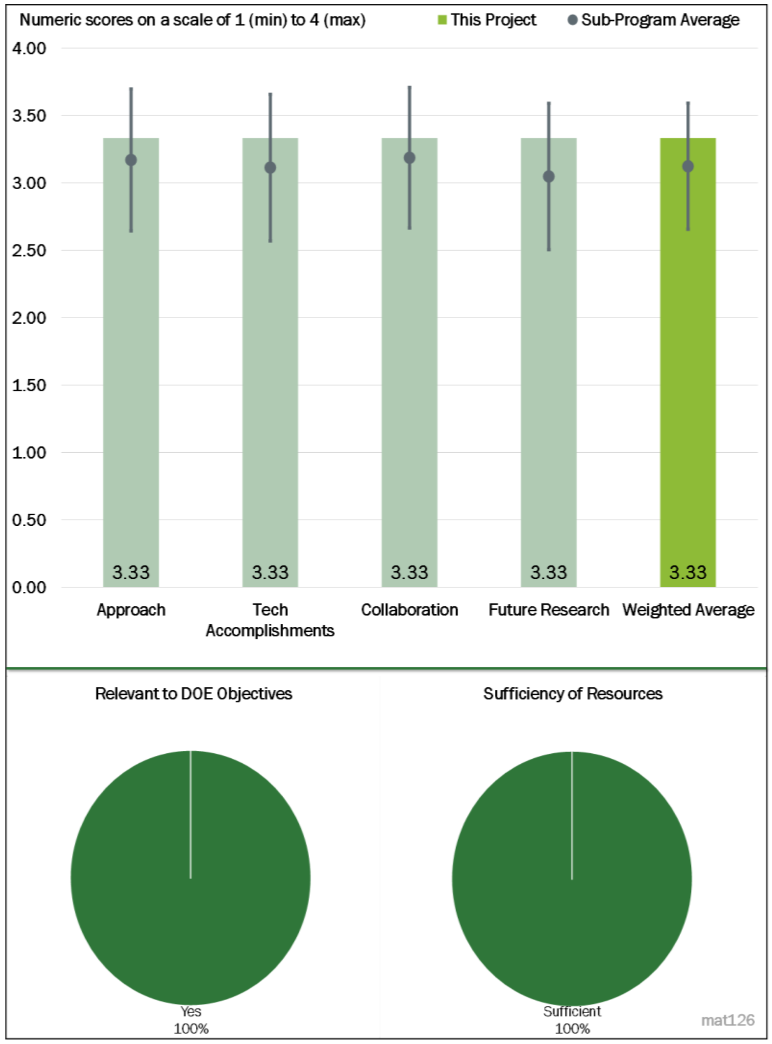

Figure 6-14 - Presentation Number: mat126 Presentation Title: Room-Temperature Stamping of High-Strength Aluminum Alloys Principal Investigator: Aashish Rohatgi (Pacific Northwest National Laboratory)

Presenter

Aashish Rohatgi, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer detailed the barriers described are to enable stamping and formability, at room temperature, of high-strength Al for structural components used in automotive applications. The project evaluates thermo-mechanical treatments and uses constitutive relations and simulations to verify that the component can be stamped at room temperature through integration of microstructure and mechanical property models. The reviewer said the experiments on the material coupled with the modeling and stamping simulations before fabricating a prototype component for full-scale testing is a sound engineering approach for addressing a difficult problem with Al alloys.

Reviewer 2:

The reviewer said that the approach of the work is generally good. The reviewer pointed out there is little information on the work that was carried out to fulfil the go/no-go gate one decision point. The reviewer asked if there are proprietary information issues associated with divulging the analyses that was carried out. The analyses seem to be important enough to be made a decision point. The reviewer thought that a presentation of projected weight reduction by component would be helpful. The reviewer said there are no targets for mechanical strength for the room-temperature formed components. The reviewer said the project team implied that they will meet or exceed the performance of the HSS they will replace, but the numerical targets should have been clearly stated still, along with other important targets.

The reviewer has a few concerns. The reviewer asked what acceptable limits are on the strain of the material/components after it/they has/have been formed at room temperature. The reviewer asked how high-strain areas are expected to perform during service at said strains (presuming that post forming heat treatments are to be eliminated to keep component costs as low as possible). The reviewer asked for instance are resultant strains/elongation just short of the material tearing acceptable (as long as no visible tearing takes place). The reviewer inquired, apart from gathering stress strain curves, what other mechanical testing will be carried out to qualify the process and components, and how will the performance of the Al components be compared with the baseline material (the HSS). The reviewer understood that no stress-corrosion cracking evaluation will take place. It appeared the PIs are heavily reliant on modeling and simulations. While modeling and simulations are essential to success, it is the opinion of the reviewer that some sort of validation needs to take place to make sure the results are accurate and can be broadly applied across the numerous components to be replaced. The reviewer said that some testing may also be prudent for the purpose of validating the results.

Reviewer 3:

The reviewer said that the formability of Al alloy A7075 at room temperature is being investigated. This high-strength alloy exhibits very limited formability and this will be a challenge. The reviewer noted that currently, this alloy is formed at higher temperatures, in the range of 225°C-250°C. The approach of using actual parts is good, but common engineering tests need to be carried out. The reviewer also pointed out that the information from current literature needs to be presented. The reviewer said what will be the difference in technology to ensure crack-free forming at low temperatures.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the results for the characterization of the mechanical properties and the friction effects during formability of the selected alloy show excellent agreement with the LS-Dyna modeling. This should improve the level of success for the next phase of component testing and prototype fabrication.

Reviewer 2:

The reviewer said that accomplishments could have been described in a bit more detail, especially in the back-up slides for the attention of the reviewers only if there was not enough time to do it in open forum. The PIs seem to be underspent by a large margin, so this bodes well for them when comparing the current accomplishments with the resources remaining to carry out the work. The reviewer remarked that the Gate 1 decision point seems to have been passed successfully. However a Gantt chart showing progress by task (as described on Slide 5) would have been more useful to the reviewer in assessing progress against tasks.

Reviewer 3:

The reviewer pointed out that only characterization of the base material is completed by developing the forming limit diagram (FLD). This is good, but actual testing needs to be carried out. Also, the project team made efforts to develop models to help future design efforts.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that the project demonstrates excellent collaboration between two national laboratories, a Tier 1 supplier, and an automotive OEM. At this advanced stage of development, involvement by academia would not be beneficial.

Reviewer 2:

The reviewer pointed out that General Motors has no Future tasks (Slide 12). The reviewer inquired if GM has accomplished all their tasks in this project (apart from reviewing the project progress and final report). The reviewer noted that Magna seems to have a central role in the project, which is encouraging. ORNL has no other role in the future as well. The reviewer noted that it was stated that Rich Davies left PNNL for ORNL, so a question the reviewer posed is whether ORNL should be listed as a collaborator, unless Rich still has a central or significant role in the project.

Reviewer 3:

The reviewer detailed that the partners include an OEM and one Tier 1 supplier; the material supplier is not included but this may not be a problem, as many commercial suppliers are available. The reviewer suggested that it would add strength if material specifications and more knowledge on performance is included, which may be available from academic researchers.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer assumed that the development of the constitutive relations for the selected alloy will include a robust model validation component. The future work as planned will contribute to overcoming the stated barriers to this technology.

Reviewer 2:

The reviewer commented that for the scope of effort, the proposed future research for the remainder of the project is outstanding because the Tier 1 supplier and the automotive OEM will be the principal performers. This will guarantee the transition of the technology and procedures to industry if test results are successful.

Reviewer 3:

The reviewer said that proposed includes work data generation for future design from the lab-scale experiments, and actual part manufacturing by the industry partner. The coordination is good but the actual plan for the part production depends on industry willingness to invest in tooling and experimentation.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer detailed that one DOE objective is to improve fuel efficiency of automobiles through using lightweight materials such as Al. These lightweight materials can be difficult to fabricate into components at a manufacturing scale because of certain mechanical properties, especially if the part manufacture is at room temperature. The reviewer remarked that this project develops a process to overcome these constraints and provides a modeling capability for iterative improvements in the process, if required.

Reviewer 2:

The reviewer commented that if successful, this work will contribute to the weight reduction target of lightweighting as laid out by the VTO (as mentioned on Slide 6; expected 30%-50% overall weight saving). The reviewer said that it remains to be seen (after the cost analyses) if the cost target will be met.

Reviewer 3:

The reviewer detailed that one DOE objective is mass reduction as it saves fuel and reduces greenhouse gas (GHG) emissions. Al can be used effectively to reduce the mass of a ferrous structure. The reviewer detailed that as more and more steel structural components are being replaced by alternate materials, it is necessary to develop information on the manufacturing and performance. This project is developing data on high-strength Al sheet material.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer pointed out this is a 3-year project that is funded at $1 million total. This is sufficient for the national laboratory to perform the initial experimentation and modeling as well as using results from the automobile manufacturer's testing to improve the models.

Reviewer 2:

The reviewer commented that the PIs are currently underspent, so it appears the funds will be sufficient. If the team keeps this spending rate, the funds will be more than enough, but that remains to be seen as the project is still relatively young.

Reviewer 3:

The reviewer said that the experiments are designed to study commercial grade Al. Quite significant information is available and efforts are needed to find and organize the knowledge.

Presentation Number: mat127
Presentation Title: USAMP Low-Cost Magnesium Sheet Component Development and Demonstration Project
Principal Investigator: Stephen Logan (FCA)

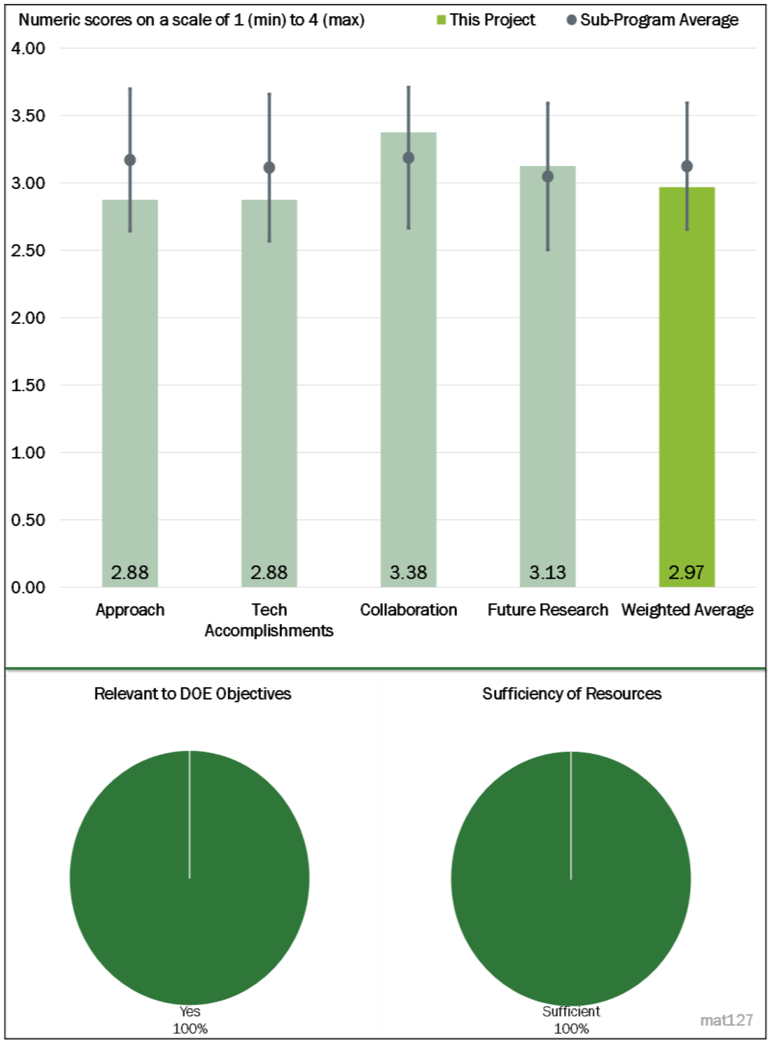

Figure 6-15 - Presentation Number: mat127 Presentation Title: USAMP Low-Cost Magnesium Sheet Component Development and Demonstration Project Principal Investigator: Stephen Logan (FCA)

Presenter

Stephen Logan, FCA

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the approach is very sound for addressing manufacturing issues of a technology at a high TRL. This is a feasibility study to demonstrate the use of a lightweight material used in automobile manufacture at a substantial cost savings. The reviewer summarized that the project starts with a technical cost analysis and goes through a material selection process and experimental sheet production followed by development of coatings, formings, and joining methods for paint shop pretreating and ends with a technical cost and performance validation. The reviewer found that this is exactly the approach and process needed to achieve a cost reduction goal for use of Mg sheet in automobile manufacture.

Reviewer 2:

The reviewer said that efforts are being proposed to develop numerical modeling capability for the entire process cycle including alloy development, rolling and forming process, prototyping, coating, and paint shop processing. This is an exhaustive study of the process and the approach proposed is quite clear.

Reviewer 3:

The reviewer said that the approach is aggressive with regard to feasibility and cost targets, which is good for as large a team and project budget as this program has been afforded. This is a positive reflection on the project. The reviewer remarked that touting ICME as a critical component seems to have fallen largely by the wayside with the abrupt selection of ATMZ3100 as the material of choice following a literature search and a few calculations. It seems that the overarching premise of using computational tools to accelerate the materials development process was largely bypassed with what turned out to be a disappointing result. The reviewer remarked the capabilities of the team as a whole in providing the breakthrough material seem somewhat underutilized when the process revealed a composition matrix that was rather ordinary (three alloys) and resulted in early testing of one (ATZM3100) that has yet-to-be-seen results. The reviewer said this was fully acknowledged as “jumping the gun,” and the reviewer asked but what was the need was for it.

Reviewer 4:

The reviewer liked the holistic approach to this project, attempting to mimic production with all of the relevant steps. However, it did not seem like the task “Alloy and sheet processing development—New Mg alloy sheet composition(s) identified” is “complete.” The question and answer session mentioned that the down-selected alloy had some issues and would need to be revisited. The reviewer said this seems like it is along the critical path, and may impact other tasks.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The viewer praised that the technical accomplishments over the past year and a half have been outstanding. The initial technical cost guidance for an automobile door panel resulted in identifying the rolled sheet metal cost as the largest cost driver, which validates the area of development needed for this component. A strip casting process was also identified as a constraint for new Mg alloys as part of this analysis. The team identified a Mg to be used in the rolling process that has improved performance at reduced rolling and forming temperatures. Coil-applied coatings were also identified from two separate suppliers and a warm-forming lubricant from two other suppliers. The reviewer detailed that the team is working with an industrial partner, and the PI was able to evaluate a potential paint shop pretreatment chemistry to work with the novel Mg alloy. CAE tools were used to evaluate the structural performance of a commercial automobile door inner and outer panels based on the commercially-available Mg sheet material. The reviewer found that, in total, this is quite a technical accomplishment given the timeframe that the work was done.

Reviewer 2:

The reviewer said that the limited results thus far seem to indicate the importance of working out the inter-company agreements before the project gets started. There was little detail on the university efforts, and it seemed that a shortcut backfired in alloy development. However, according to the reviewer the investigators seem to be moving along well in the areas of coatings and lubricants.

Reviewer 3:

The reviewer detailed how the project team established a consortium with various partners from a material supplier, academic institutions, DOE national laboratories, and industry partners. The team tested a new alloy; even though the performance of this new alloy is not up to expectations, the team is preparing for a new alloy development. The reviewer also pointed out that the cost modeling is completed with the identification of drivers, which need to be optimized to reduce the cost of the material.

Reviewer 4:

The reviewer said that the coatings approach on ZEK100 was interesting work and represented an appreciably large level of effort. The reviewer said it appeared that this is producing results that will have broader application. The bulk of the program at this point seems to be focused on commercially-available alloys (E-form Plus, and ZEK100). The reviewer inquired if adding process steps (coating) to these alloys going to get us anywhere near cost targets. The reviewer expressed having difficulty gleaning this information or the cost comparison with ATZM3100 from Slide 7.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer exclaimed that this project demonstrates an outstanding collaborative effort amongst 16 performers and 3 automobile manufacturers. The reviewer has not previously reviewed a project with this much collaboration.

Reviewer 2:

The reviewer said including LightMAT is a positive from the standpoint of collaborations, and there are no weak points here at all—a broad team with widespread capabilities and adequate involvement from industrial partners.

Reviewer 3:

The reviewer remarked that the team has been formed and is effectively communicating with monthly and quarterly meetings. The technical team from the United States Automotive Materials Partnership (USAMP) is discussing the progress weekly. The reviewer commented the team covers all the aspects of the process being studied.

Reviewer 4:

The reviewer remarked that the project has a strong group of stakeholders. It is not clear how all of the university efforts will be coordinated.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that although this project is in its early stages, the planning and milestones/decision points reflect an outstanding schedule for achieving the goals of this project and overcoming the barriers and challenges. The reviewer found that the schedule is maintained and milestones are met, no alternate development pathway will be needed.

Reviewer 2:

The reviewer pointed out that there remains a large component of the ICME-based work that will assist in sheet processing, so that is eagerly anticipated. The reviewer cautioned that not enough work has been done yet to indicate that ATZM3100 is the answer to the material cost issue (while maintaining performance measurables)—so the focus on future work that processes this material as the only avenue for material development runs the risk of a very strong program concluding that commercially available products are superior to what was developed by a very capable team, with little additional data on the Mg development process that might help future development efforts.

Reviewer 3:

The reviewer said that there seems to be a great deal of production challenges to overcome in Tasks 2 and 5, and these feed into Tasks 1, 3, 4, 6, and 7. The reviewer cautioned that modeling effort, particularly in atomistic crystal plasticity modeling and constitutive modeling, will be a challenge, and delays in production will significantly reduce the time these efforts are allotted.

Reviewer 4:

The reviewer remarked extensive work needs to be completed, and that alloy development will be the bottleneck for the project. The reviewer said that castability of the new alloy will be a challenge to overcome, and the supplier’s experience in the alloy development may help to reduce the risk.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer found that this program is squarely within the DOE objectives of energy efficiency through the lightweighting of vehicles. Programs such as this enable the deployment of lightweight technologies in the marketplace by increasing the cost-effectiveness.

Reviewer 2:

The reviewer remarked that this project supports an overall objective of DOE. One objective of DOE is to improve fuel efficiencies in automobiles through using lightweight materials such as Mg. The current high-cost of Mg sheet metal and the challenges in manufacturing automobile components with it prevent widespread use in the automotive industry. The reviewer detailed that this project addresses the barriers and challenges of using Mg sheet from an initial technical cost analysis through material selection, component manufacture, and final technical cost and performance validation.

Reviewer 3:

According to the reviewer, Mg is one of the materials which can be effectively utilized to reduce vehicle mass. The potential of this material is much higher than steels and Al. The reviewer pointed out, however, the cost of the material is a barrier and efforts to reduce the cost are always welcome.

Reviewer 4:

The reviewer acknowledged that the end goal is quite relevant. However, according to the reviewer there was a clear go/no-go missing from the approach. The cost model indicates that the biggest cost driver is the raw material. The investigators acknowledge that this is a critical assumption and out of the project scope. Given the geographic location of raw Mg sources, the reviewer asked the program managers, “Is now the right time?” The reviewer could see both sides, either continuing the project to get ahead of production problems for the day that the cost model or price point changes, or choosing to end the project so that the results will not get stale on the shelf. The reviewer wanted to be clear in expressing a belief that even with the challenges encountered, the team of investigators will conduct a successful project. Rather than doubt of the project team’s abilities, this reviewer clarified that the question should be taken as raising a point about a geopolitical situation that beyond the project team’s control.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer noted that the team is large, but the funding level is commensurate with the effort.

Reviewer 2:

The reviewer said that this is a large amount of funds for this project; however, there are a multitude of performers and collaborators that could justify the funding. If successful, the investments in materials development will be far exceeded by the cost savings by industry through using this material and processes.

Reviewer 3:

The reviewer pointed out that nearly $3 million is planned for the current FY. The reviewer said that many tasks associated with the manufacturing process, such as rolling mill lubricant, coating, and paint baking response of the sheet material, are being planned.

Reviewer 4:

The reviewer said that the overall resources are sufficient, the reviewer has some questions on resource allocation. Currently, the project seems heavy on production and fabrication, but thin on the computational side. The reviewer remarked that a great deal lies on the success of the next alloy developed.

Presentation Number: mat128
Presentation Title: Development of Low-Cost, High-Strength Automotive Aluminum Sheet
Principal Investigator: Russell Long (Arconic)

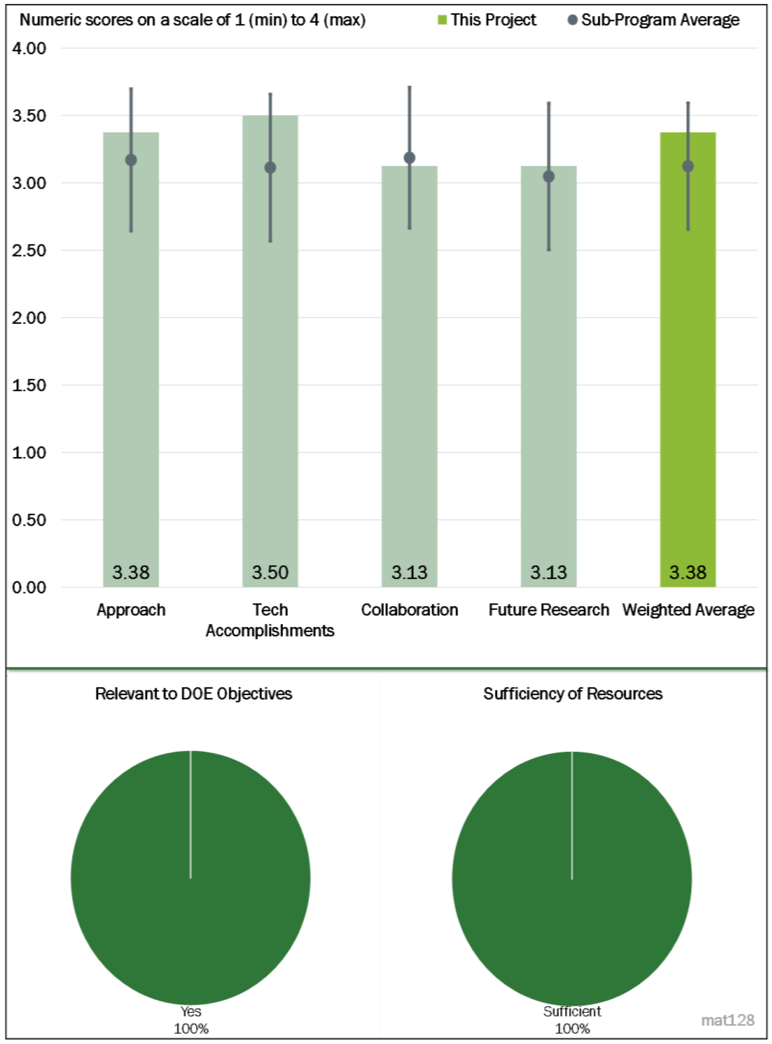

Figure 6-16 - Presentation Number: mat128 Presentation Title: Development of Low-Cost, High-Strength Automotive Aluminum Sheet Principal Investigator: Russell Long (Arconic)

Presenter

Russell Long, Arconic

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer detailed that project objectives are to develop an Al alloy with specific mechanical properties within a specified processing temperature and specific cost for the finished product. The project is well-designed and feasible to meet these objectives with an approach that starts with alloy development and proceeds through tool design, process development, material property characterization, and ending in a cost study.

Reviewer 2:

The reviewer commented that the plan is good with partners form the whole spectrum of the supply team. The work includes the cost model as well as material optimization.

Reviewer 3:

The reviewer pointed out that the work is 80% complete, so most of the work has been carried out.

The reviewer detailed that cost modeling was done on the 2.4 mm thick material, instead of the 2.5 mm material. The reviewer asked what the implication is of the approximately 12% reduction in strength of the 2.4 mm material compared with the 2.5 mm material. The reason why the 2.4mm material was chosen for cost modeling over the 2.5mm materials is not clear to the reviewer. Testing was limited to only one configuration of component. The reviewer said this does not seem enough to establish confidence that the results will be similarly good for other component forms. The reviewer asked if there are any plans to test more component forms, especially as this process will be applied to more than the tested component form. The reviewer said that not enough detail is provided about the corrosion testing to be performed. The reviewer described that more detail about what went into the calculations of the cost per lb saved needs to be presented. For instance, what is “recycled scrap credit” and how was that applied to reach the $2/lb The reviewer inquired if the 2.5 mm material was considered, how much will the weight savings cost be.

Reviewer 4:

The reviewer remarked well-designed study. The results would have been improved by a deeper analysis of the failures in the bend and weld study.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer acknowledged that a lot of work was done and results obtained. These data will help achieve the overall goal of weight savings at a reasonable price

Reviewer 2:

The reviewer commented that the project appears to have met performance requirements.

Reviewer 3:

The reviewer pointed out that the project period is four and a half years. The reviewer summarized that a large amount of research and development has been conducted over this timeframe with some significant technical accomplishments in material forming/tooling, forming simulation, new Al alloy development, component fabrication and testing, material selection, prototype testing, corrosion evaluation, joining trials, and a cost analysis resulting in significant weight savings and a cost per pound saved close to the target of $2/lb. According to the slide on Remaining Challenges and Barriers, there are still some improvements and additional information needed to meet all of the objectives for this project. The reviewer commented this will be difficult to accomplish with the remaining time of 6 months left on the project.

Reviewer 4:

The reviewer remarked that iterations on the alloy composition have been conducted to obtain a compromise on formability and strength. The alloy’s highest strength does not exhibit targeted ductility. The reviewer noted that the qualification testing procedure has been developed and will be used to compare the test alloys. Also, actual parts have been fabricated using a test die. The reviewer found that all aspects of a development project have been properly planned and coordinated. Also, the efforts on tailor welded blanks needs to continued, which will further reduce the material use.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that collaboration involves a national laboratory, a materials producer, a Tier 1 supplier and an automobile OEM. The level of testing can be easily performed by the national laboratory or the materials supplier so involvement by academia would not be required for the technology at this readiness level. The reviewer found that the presenter also showed good coordination between the materials producer and Tier 1 supplier when processing equipment was moved to another production line.

Reviewer 2:

The project team is vertically integrated with an OEM, Tier 1 supplier, material provider, and a national laboratory. The design requirements are provided by an OEM, and a Tier 1 supplier is conducting experiments. The reviewer pointed out that variations of the alloy are being produced by the material supplier. The results presented indicate a compromise on the strength and formability. The reviewer remarked well-planned and executed project with proper coordination.

Reviewer 3:
The reviewer said that there seems to have been good collaboration amongst the partners. It would have been nice to know what percentage of the work each collaborator contributed to.

Reviewer 4:
The reviewer observed that partners seem to play a passive role. For example, Honda only provided formability and corrosion targets when it could have been involved in the analysis. The reviewer said that the impact of other partners is unclear.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted that this project is concluding in the next 7 months, so there is not the time or the funding to address the proposed future work. Improvements sought through further forming trials and joining quality will likely not be achieved and the additional cost reduction options cannot be effectively pursued because of lack of data from the forming trials.

Reviewer 2:
The reviewer remarked good future work and approach. The reviewer noted that the corrosion testing approach is not discussed.

Reviewer 3:
The reviewer said that the project has incorporated appropriate decision points and is considering technology and implementation barriers. The reviewer noted that risk mitigation is not well described.

Reviewer 4:
The reviewer said this is the last year for the project.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that high-strength Al sheet is necessary to meet the weight reduction targets of DOE as more and more HSS structural components need to be replaced. This project addresses this concern by encouraging the development of high-strength alloys.

Reviewer 2:
The reviewer said yes, and elaborated that the development of high-strength, lightweight, low-cost alloys that are formable is an ambitious task and highly relevant to DOE. The results of this work could have a significant impact on the automotive industry.

Reviewer 3:
The reviewer agreed that this project supports an overall objective of DOE. One objective of DOE is to improve fuel efficiencies in automobiles through using lightweight materials such as Al. The current challenges in manufacturing automobile components with Al prevent full use in the automotive industry. The reviewer said that this project attempts to solve some of the issues with material properties, parts processing, and component joining coupled with a cost study.

Reviewer 4:
The reviewer commented that the project contributes to weight reduction at reasonable vehicle cost targets for VTO.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked resources are sufficient and the project was able to achieve its milestones.

Reviewer 2:

The reviewer noted that project length is 4-1/2 years at a total cost of about $4.8 million, which is about $1 million per year. This should be sufficient to achieve the stated milestones in a timely fashion. The reviewer said that for reasons not totally explained by the presenter, there is still some significant work to be done with very little time to accomplish the final results.

Reviewer 3:

The reviewer said that there seem to be enough resources to complete this work, going by the word of the PI. Without opening the books and reviewing expenditure by task projection and actuals, there is really no way of confirming that the team has sufficient funds to complete this work.

Reviewer 4:

The reviewer said last year of the project; no funding request.

Presentation Number: mat129
Presentation Title: Optimizing Heat-Treatment Parameters for 3rd Generation Advanced High-Strength Steel Using an Integrated Experimental Computational Framework
Principal Investigator: Xiaohua Hu (Pacific Northwest National Laboratory)

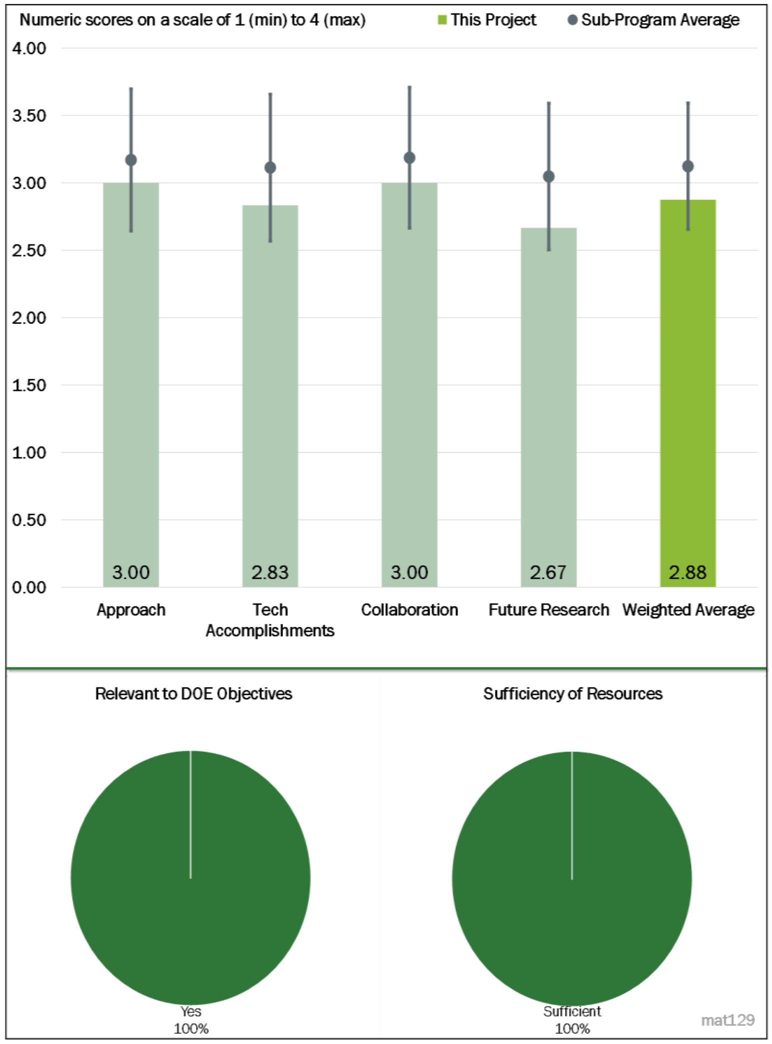

Figure 6-17 - Presentation Number: mat129 Presentation Title: Optimizing Heat-Treatment Parameters for 3rd Generation Advanced High-Strength Steel Using an Integrated Experimental Computational Framework Principal Investigator: Xiaohua Hu (Pacific Northwest National Laboratory)

Presenter

Xiaohua Hu, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the flow diagram for the approach illustrates a well-designed and systematic process for obtaining the needed information to meet the project objectives and to address the barriers and challenges with the use of third-generation advanced high-strength steels (3GAHSS). The approach is feasible in concept but has not completely answered all the questions surrounding the use of these materials.

Reviewer 2:

This reviewer found it challenging to follow the approach of the work, although the objective of the work seems straightforward and clear. The reviewer detailed the project’s approach, describing that the relevance and objectives are development of an integrated in situ and ex situ experimental and numerical modeling framework for Med-Mn 3GAHSS to: determine accurate thermodynamic parameters; optimize inter-critical annealing parameters, microstructure, and superior combined mechanical properties of ductility and strength suitable for vehicle lightweighting; meet DOE VTO Multi-Year Program Plan targets and goals; and help steel makers and users expedite the development to deployment cycle.

The reviewer found that the way the work was laid out was not optimal. It was difficult to follow how the tests, as well as the modeling and simulation work carried out, fit together to build the numerical framework. The reviewer said that this needs to be clarified better. The reviewer suggested it may be prudent to start with a list of parameters that must be used to develop the framework for each subgoal, why they are important (define the physical meaning and significance of each parameter; e.g., PLP, AI parameters, what are they, what are the physical meanings and why are they important to this framework); and how they would be obtained. The reviewer cited, for instance, will experimental work be required to provide input data for simulations used to develop the framework.

The reviewer described that one of the difficulties of this work seems to be that the authors may be trying to take on too many things at the same time. However, the exercise described above might help determine this, and whether one framework model or more are required to reach each of the subgoals detailed above. The reviewer is not satisfied with the approach with regard to model validation. Model validation must be carried out with data not originally used to develop models or submodels for this work. The reviewer found that the presentation did not describe in any degree of detail how model/framework validation will be achieved.

Reviewer 3:

The reviewer said that the project is aimed to develop numerical models to predict the final response of the alloys for heat treatment. Heat treatment is a complex process with diffusion, precipitation, and growth phenomenon occurring simultaneously, impacting the final structure and hence properties. Most of the times the development is through a trial and error process making it expensive and time consuming. This project is planning to conduct experiments and measure the kinetics of these reactions to develop modeling of the process. This will help designers see parameters.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed that there has been outstanding progress in the technical accomplishments for most of the project objectives in order to meet the performance measures and milestones, e.g., in situ inter-critical annealing heat treatment experiments, ex situ heat treatment materials characterization, simulations for phase transformation during inter-critical annealing, phase field microstructure modeling and microstructure, and mechanism-based phenomenological and crystal plasticity finite element modeling. The reviewer said that there is still more materials and data to be generated and not much time to obtain accurate models.

Reviewer 2:

The reviewer commented that a new in situ characterization technique of steels during heat treatment had been developed. This is used to measure the retained austenite and its stability. The reviewer also pointed out that the presence and amount of C and Mn on the precipitated phases can be estimated. This will help to model the diffusion and precipitation process. The reviewer noted that this effort will be supplemented by external characterization. Per the reviewer, the project successfully completed modeling efforts on the Luder Band formation during the transformation.

Reviewer 3:

The reviewer described how the “Fair” rating is based on the fact that the work was difficult to follow, and hence it is also difficult to gauge the impact of the eight accomplishments listed on the overall success of the work. The reviewer said that clearly defining what needs to be done will go a long was in helping to properly assess the impact of the current accomplishments on meeting the overall goals of the work.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer detailed that listed collaborators include Colorado School of Mines, Argonne National Laboratory, and ORNL. The task of each team member is fairly well spelled out. The reviewer said each team member should help one another in better defining the scope of work, and making an assessment as to whether too many things are being crammed into the framework.

Reviewer 2:

The reviewer remarked three U.S. DOE national laboratories are in collaboration with the steel research center at the Colorado School of Mines in this project. The steels are being supplied by industries involved in the steel research center at Colorado School of Mines.

Reviewer 3:

The reviewer observed that collaboration is limited to three DOE national laboratories and the Colorado School of Mines without involvement from Tier 1 suppliers or OEMs or multiple academic institutions. This was a reviewer comment at last year's AMR and is addressed on Slide 17; however, there is still no description of how the results of this $1.3 million project will transfer to industry, other than through the academic institution. The reviewer noted that although the project is addressing issues at an early-stage of research, the Colorado School of Mines should still be able to identify technology transfer partners for this project, which will end in another year.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer pointed out that confirmation of the models by measurements needs to be completed.

Reviewer 2:

The reviewer said that although the project was effectively planned, the future work described is a significant amount to be accomplished with only 15 months left on a 4-year project that is stated to be 50% complete in June 2018. The two remaining milestones were presented as "on track;" however, there is a large amount of studies and development left to perform in a very limited time.

Reviewer 3:

The reviewer remarked that this is also given a "Fair" rating based on the fact that the work is difficult to follow, and hence a difficulty exists in figuring out whether the future work as defined will be enough to reach the stated goals. The work being better defined will go a long way in helping to make this assessment more accurately.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer remarked this project supports an overall objective of DOE to improve fuel efficiencies in automobiles through using lightweight materials such as 3GAHSS. The lack of fundamental understanding and quantitative measurements of alloying content, heat treatment parameters, microstructure, and mechanical properties coupled with the challenges in manufacturing automobile components with it prevent widespread use in the automotive industry. This project addresses the barriers and challenges associated with traditional heat treatment processes of 3GAHSS.

Reviewer 2:

The reviewer pointed out that the development of good AHSS would assist in reducing the overall glider weight of vehicles, which is a stated goal of VTO. If this framework delivers as promised (based on the four sub-goals), AHSS development and manufacturing would be easier, faster and probably cheaper. These are all good things for vehicular glider weight reductions.

Reviewer 3:

The reviewer noted how HSS are one of the ways to reduce the weight of the vehicles without compromising the safety. The HSS always require heat treatments to improve the properties and a trial and error process of optimizing this process is expensive. The reviewer remarked understanding the physics and developing models will pave way for faster development process and confidence in the materials.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer found that the estimated cost of 700,000 will be sufficient to complete the planned tasks.

Reviewer 2:

The reviewer pointed out this is a 4-year project funded at $1.3 million (DOE and in-kind). This is about $300,000 per year, which is sufficient for the level of research being conducted by various laboratories and should achieve the stated milestones within the project period.

Reviewer 3:

The reviewer said that this is difficult to determine, and the review had to choose an option.

Presentation Number: mat130
Presentation Title: Enhanced Sheared Edge Stretchability of Advanced High-Strength/Ultra-High Strength Steels
Principal Investigator: Kyoo Sil Choi (Pacific Northwest National Laboratory)

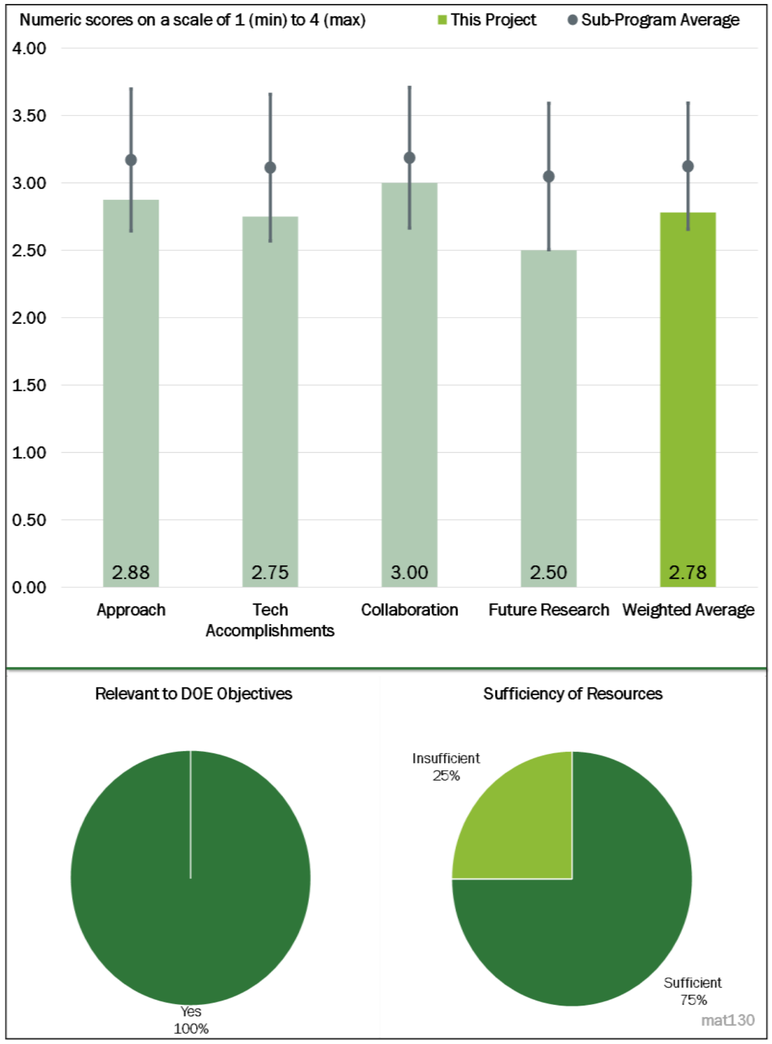

Figure 6-18 - Presentation Number: mat130 Presentation Title: Enhanced Sheared Edge Stretchability of Advanced High-Strength/Ultra-High Strength Steels Principal Investigator: Kyoo Sil Choi (Pacific Northwest National Laboratory)

Presenter

Kyoo Sil Choi, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer described that using advanced materials such as AHSS and ultra-high strength steels (UHSS) in automobile manufacture is hindered because of damage occurring during fabrication of component parts, in this case trimming the edges of the component part. Stretchability at the material’s edge is an important factor. The reviewer found that the approach used in this project starts with a literature review and continues through characterization of material properties, simulations and experiments, and ends with optimizing cutting parameter using predictive analysis to enhance the stretchability at the materials edge. The reviewer remarked this is a sound approach to solving any material defects problem.

Reviewer 2:

The reviewer remarked that the approach was largely successful in achieving program goals, so there is little to fault from that standpoint. The reviewer noted that successful validation of a modeling approach is always a bit subjective, however. The dependence upon edge shapes and macro-scale deformation models lacked a bit of detail—more microstructural characterization of incremental deformation modes as well as detailed fracture surfaces would have been a very valuable information set to add to the program curriculum.

Reviewer 3:

The reviewer said that the team has used tensile testing and some analysis of microstructure to improve on enhanced sheared edge stretchability. The reviewer cited as an example how the team was able to determine that strength differences in microstructural components contributes to poorer stretchability and reducing this by heat treatment can improve on this. However, according to the reviewer these simple tensile tests are too simple and do not take into account the complexity of 3-D geometry such as the hole punch shown. The reviewer asked what the effects are of rolling direction, and of rate of shear, etc. The reviewer said that all of these effects are not being considered.

Reviewer 4:

The reviewer commented the quantitative approach does not identify the root cause formability difference between material supplied by Supplier A and Supplier B. The volume fraction/presence of voids was not considered in the conclusion. It seemed to this reviewer that a hypothesis of relative hardness between martensitic and ferritic phase was proven rather than a scientific assessment of the contribution associated with the hardness differential between the dual phases of each material. The notion and comparison between to performance of a dull punch versus sharp punch signifies the elementary approach taken to a complex problem.

The reviewer commented that the solution to temper the martensite to reduce the hardness differential between the phases is a means to prove the hypothesis. Rather, the comparison of a tempered material proved that lower strength material has better edge stretch formability than a higher strength material.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found that the results for materials characterization for two steels and the comparison of edge stretchability met the performance objective of obtaining a fundamental understanding of the role of microstructure on sheared edge stretchability. The successful results of using computational methods and comparisons with experimental data met the performance objective of building a predictive capability to quantify relationships between microstructure and characteristics of the material at its edge. Computational results were also successful in predicting trimming induced damage.

Reviewer 2:

The reviewer commented that there is certainly value in the accuracy of the modeling tool in predicting trim-induced damage, not only from the standpoint of optimizing the process but also for understanding the time-dependent degradation of the process as trim tools wear.

Reviewer 3:

The reviewer observed that the project team was able to conclude that heat-treating DP2 steel improved on stretchability. However, the reviewer asked what impact this heat treatment has on other properties of the material, and if this is a realistic solution. The reviewer inquired what the best solutions are to improving on the stretchability of the high-strength and ultra-high-strength alloys.

Reviewer 4:

The reviewer remarked that work was completed; however, the intrinsic value of the technical accomplishment is minimal if any.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer observed the program has an ideal mix of talent/experience/capabilities, with an OEM and two producers supporting the scientific efforts. The reviewer would have liked to see the breakdown for cost-share partners as a matter of interest (the reviewer asked how much the steel producers contributed and was it materials only or cash/in-kind as well).

Reviewer 2:
The reviewer said that this project demonstrated outstanding collaboration involving a national laboratory, academia, two steel manufacturers, and an automobile manufacturer. The reviewer said that coordination amongst these partners resulted in achieving the project objectives within the period of performance.

Reviewer 3:
The reviewer acknowledged that collaboration took place. The reviewer would expect better guidance by the industrial partner to yield a meaningful result.

Reviewer 4:
The reviewer said that although reasonable work has been done in the modelling, given that this is the final year of the project and only thin tensile samples are being evaluated, and only at a limited scale, the collaboration with partners appears minimal.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that the program is 95% complete and seems to be on target.

Reviewer 2:
The reviewer remarked there is no proposed future research; the project has ended.

Reviewer 3:
The reviewer said the project has ended this month.

Reviewer 4:
The reviewer commented work is done, nothing gained.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer pointed out using HSS and UHSS will reduce mass and increase efficiency. Improvements that enable the use of these steels support DOE objectives

Reviewer 2:
This project supports an overall objective of DOE to improve fuel efficiencies in automobiles through using lightweight materials such as AHSS. The challenges such as edge stretchability during forming operations in manufacturing automobile components with it prevent widespread use in the automotive industry. This project addresses the barriers and challenges of using AHSS from an initial literature review through material selection, component testing, and predictive modeling.

Reviewer 3:
The reviewer commented the topic of edge stretch formability is relevant. The value of the result is minimal.

Reviewer 4:
The reviewer remarked it requires some level of imagination to understand specifically what the cost targets are and whether they were achieved. What is the manufacturing estimate of cost savings—the reviewer asked if it is based on material feasibility, or reduced scrap rate. The reviewer said it may be a complex combination of many factors, but this was not elucidated.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said with 100% completion essentially at hand, the resources were apparently adequate.

Reviewer 2:

The reviewer said that the project period of performance is 3-1/2 years and the over-funding level is $1.35 million, which is about $385,000 per year. This is sufficient funding for the level of research being conducted and the number of partners involved.

Reviewer 3:

The reviewer found that resources were sufficient, and increased involvement by industry in the planning phase would have provided a more meaningful result.

Reviewer 4:

The reviewer commented that based on what was shown and that the project is now completed, this reviewer did not believe enough was achieved with the milestones to effectively solve the problems with edge stretchability.

Presentation Number: mat131
Presentation Title: Corrosion Control in Carbon Fiber Reinforced Polymer Composite—Aluminum Closure Panel Hem Joints
Principal Investigator: Brian Okerberg (PPG Industries)

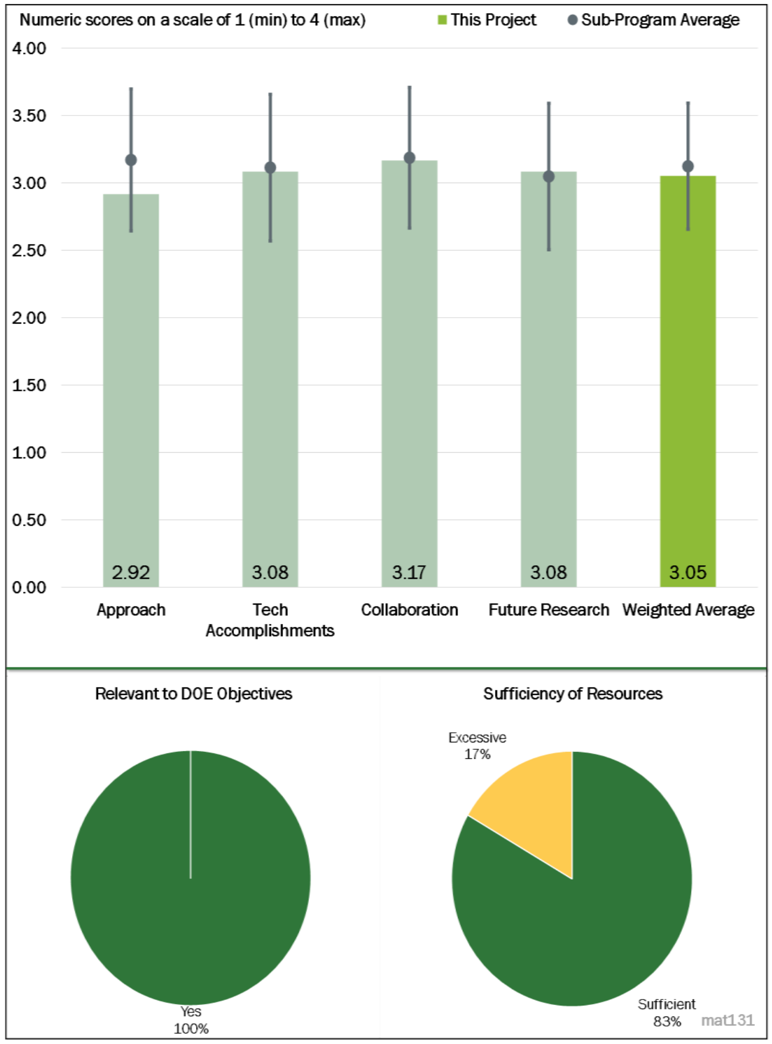

Figure 6-19 - Presentation Number: mat131 Presentation Title: Corrosion Control in Carbon Fiber Reinforced Polymer Composite—Aluminum Closure Panel Hem Joints Principal Investigator: Brian Okerberg (PPG Industries)

Presenter

Brian Okerberg, PPG Industries

Reviewer Sample Size

A total of six reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that including both types of CFRP (twill and continuous fiber) will cover the future production options. The development of an adhesive and conductive primer will be required to make this combination viable.

Reviewer 2:

The reviewer remarked that the project precisely addresses the technical objectives. The design is definitely near-commercial readiness level although it is not highly novel from research and development standpoint. The materials formulation was randomly chosen but more keeping commercial readiness in mind rather than developing a research hypothesis for expanding or contributing to science.

Reviewer 3:

The reviewer said that this addresses a broad class of structures that are not practical today because they are incompatible with existing industry curing temperatures.

Reviewer 4:

In this reviewer’s opinion, this project has an Edisonian approach. The reviewer did not see any solid chemical/electrochemical background and their interrelation for this work. The reviewer said that some degree of basic science and explanations of the results are always a must in any technical project. Slide 10 has an indication of all the parameters that are considered for the development work, which is a positive step, but no results (reasons, base, or fundaments) are explained and even, at a low- or small-level, explanations and reasons of the results are needed for the “prediction” of the effects. The reviewer remarked that an electrochemical model will be even better for future applications.

Reviewer 5:
The reviewer observed a good approach, but recommended a numerical versus an observation approach.

Reviewer 6:
The reviewer commented the presentation material failed to provide a comprehensive plan on how the technical barriers would be addressed. A reference to predictive accelerated corrosion tests was included in the Technical Challenges; however, the overall plan did not reference how to address predictive modeling. The reviewer noted that Budget Period 1 referred to understanding the nature and the extent of a problem from a fundamental point of view, but no references to fundamentals was covered in the presentation material. The reviewer recommended the team reassess the project plan and milestones to reflect how the activities provide a fundamental understanding into the project objectives. The reviewer noted that joining Al to CFRP at 150°C for 10 minutes for hem flange adhesives for closures require the development of suitable test techniques relevant to size and geometry associated with closure system.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer reported that there is good progress being made on initial corrosion testing and development of primer and adhesive that meets the 150°C at 10 minute cure cycle. The coefficient of thermal expansion (CTE) mismatch will be difficult to accommodate. The reviewer observed that the project team's CTE samples, which show the bowing on Slide 15, should be longer (close to the length of a door or hood edge if that is the target condition).

Reviewer 2:
The reviewer observed a good level of activity and accomplishment.

Reviewer 3:
For this reviewer, there were no questions that progress has been made. Now, the question is if this progress has been made systematically, and if the next step is then taken based on an analysis of the prior results and its conclusions. The reviewer expressed interest in seeing a table with indications of a path as a function of already-achieved results.

Reviewer 4:
The reviewer noted that this is the first year of the project so the majority of work has not been initiated.

Reviewer 5:
The reviewer recommended that the project team should conduct a temperature sensitivity and present this at the next AMR to elucidate if the chosen low-cure adhesive is at the optimal performance at the chosen temperature.

Reviewer 6:
The reviewer referenced prior comments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said that there seems to be active participation between Ford, The Ohio State University, and PPG.

Reviewer 2:
The reviewer remarked that it seems like very good collaboration across teams, and the OEM is actively engaged.

Reviewer 3:
The reviewer found that from the provided information, it seemed that a good collaboration and interaction exist between these three organizations. The reviewer noted how produced samples are sent to different organizations for their evaluations. The reviewer noted that all of the involved organizations are well-known and recognized.

Reviewer 4:
The reviewer recommended that the project team should consider how activities from one partner support the rest of the project. For example, the authors made references to electrochemistry technical accomplishments, but the reviewer did not see or recall from the verbal portion of the presentation how such findings support the overall project or what targets are necessary to be achieved from an electrochemistry point of view to deal with barriers the project is supposed to address.

Reviewer 5:
The reviewer recommended that collaboration with the OEM needs be increased to ensure relevance.

Reviewer 6:
Good blend of industry and OEMs.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer noted a well laid-out plan that addresses several aspects of the technology that require development in order to deploy production.

Reviewer 2:
The reviewer said that this project has listed continued development of the adhesive for high CTE mismatch and conductive primers for use of low-temperature e-coat. The project team will be evaluating alternative joint designs including the baseline hem design. The reviewer believed the CTE samples should have lengths similar to the joint length in a door or hood application.

Reviewer 3:
The reviewer remarked that the proposed future research appeared to be somewhat decoupled, and there were no references at all to predictive modeling.

Reviewer 4:
The reviewer observed future work depicted on Slide 19, which indicated numerous future experimental steps, mainly about producing samples and subsequently subjecting them to evaluative testing. The conclusions and decision made, based on theoretical needs, are missing and needed to direct the next experiments. Furthermore, according to the reviewer these results could help feed a model or/and further develop a model, even if this model is basic at this moment, but will build the base for a better model later.

Reviewer 5:
The reviewer recommended that it would be good to include even continuous CF, which is more prominently used in automotive owing to their high mechanical performance.

Reviewer 6:
The reviewer recommended that future research be quantitative versus qualitative in nature.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said the project is well-aligned to DOE objectives.

Reviewer 2:
The reviewer pointed out that joining of material with different CTE mismatch is a very fundamental problem which needs to be addressed.

Reviewer 3:
The reviewer responded that the researchers are using automotive future materials in joint configurations similar to those expected to be used. The corrosion and CTE impact on those samples are being studied per DOE goals.

Reviewer 4:
The reviewer saw that this project is very relevant. The need to quantify the interactions between materials is imperative to realize multilateral lightweighting objectives.

Reviewer 5:
The reviewer remarked the project addresses new material combinations that today are not practical but would provide significant weight savings.

Reviewer 6:
The reviewer expressed a preference for answering this question with “Partially,” and it is not possible under the two only available answers. The reviewer really thinks that this research should be done completely and totally by the car industry together with the resin/coating (chemical) company. These entities will be the beneficiaries of this technological approach indirectly (and from here come this reviewer’s “partially” grade). The reviewer said that DOE should be more involved in areas where the investment is “too risky or too costly” for the private world and (in this reviewer’s very personal opinion), and this project does not meet this standard.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the team appears to be on track with their milestones.

Reviewer 2:
The reviewer said that it appears sufficient resources are deployed.

Reviewer 3:
The reviewer remarked that the team has requisite resources.

Reviewer 4:
The reviewer said that resources are appropriate.

Reviewer 5:
The reviewer thought yes, the team can (and they surely) meet all the project milestones in a timely fashion. The resources, manpower, and institutions are there.

Reviewer 6:
The reviewer said more engagement by an industry partner is needed.

Presentation Number: mat132
Presentation Title: High-Strength Steel-Aluminum Components by Vaporizing Foil Actuator Welding
Principal Investigator: Glenn Daehn (Ohio State University)

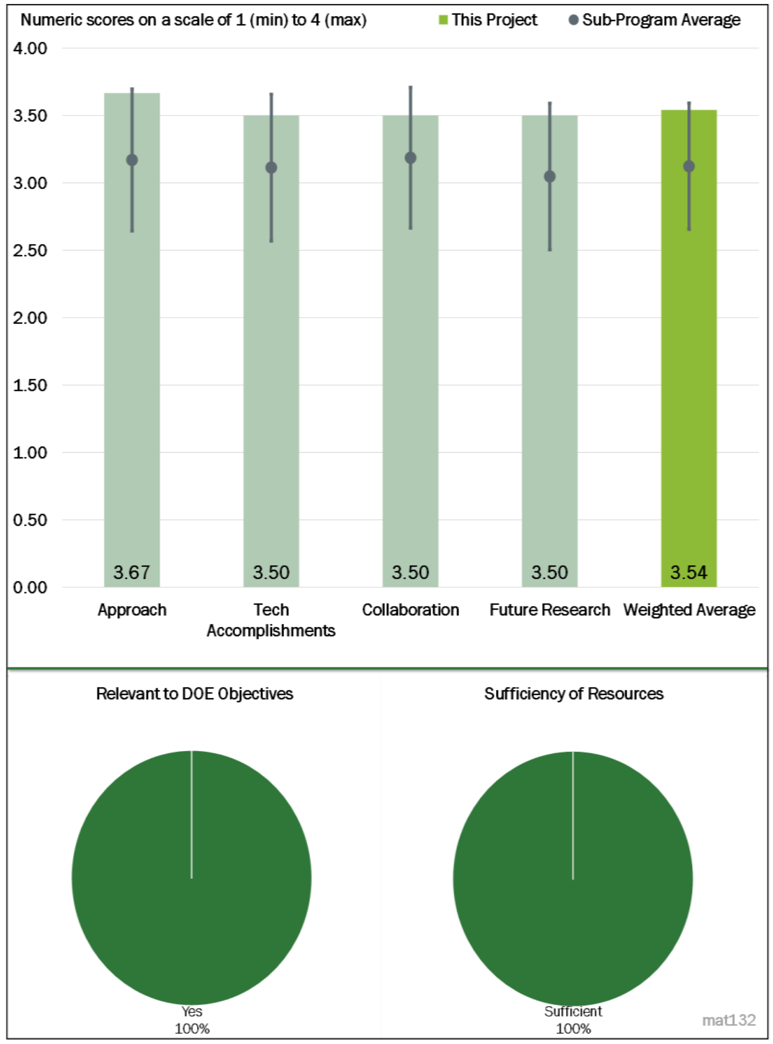

Figure 6-20 - Presentation Number: mat132 Presentation Title: High-Strength Steel-Aluminum Components by Vaporizing Foil Actuator Welding Principal Investigator: Glenn Daehn (Ohio State University)

Presenter

Glenn Daehn, Ohio State University

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the approach is designed to accelerate and focus the development of a method for joining dissimilar materials in an expedient manner. The approach is to start with a known technology, vaporizing foil actuator welding, and optimize it for joining Al to HSS. The reviewer pointed out that both are considered lightweight materials by the automotive industry. The approach is sound from the aspect of starting with coupon selection and moving through coupon testing, prototype component fabrication, production and testing of the prototype component, and ending with the design and construction of a production-scale robotic welding system. The reviewer noted that throughout the project, part of the approach is to do numerical model development and model validation using test data to improve the process.

Reviewer 2:

The reviewer said that the approach presented appeared very logical.

Reviewer 3:

The technical objectives are well laid out with an apt feasibility plan. There is not any fundamental issue being addressed, but the technology being developed takes into consideration the commercial-readiness for which state, it is aptly proposed and planned.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer said that good progress has been made, and the team is on course to meet proposed objectives.

Reviewer 2:
The reviewer said that although the project is only 30% complete, there has been excellent progress and results for the welding of five different pairs of Al-steel coupons, good results for corrosion testing, and good characterization of intermetallic compounds formed during the welding process. Development of a prototype welder has begun and a computational model has been validated on the interface morphology of an Al-steel weld. The reviewer noted that the team selected a prototype component, the engine cradle for a 2016 Chevrolet Cruze, for the full-scale testing. The reviewer found that all of these demonstrate outstanding progress to date for a project that is only one-third through the performance period.

Reviewer 3:
The reviewer expressed a bit of concern with the delay of the prototype design, supporting CAE results, and the impact it could have on the timely finish of the project. The reviewer highly encouraged the team to include activities at coupon or component level for the sensitivities in bond gap, and the necessary control of bond gap to achieve optimum joint strength performance.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer observed great collaboration within the team.

Reviewer 2:
The reviewer found that the collaboration for this project is excellent because it involves a national laboratory, three materials suppliers, a testing company, an equipment builder, and a university. The reviewer recommended it would be good to have an automobile manufacturer involved; however, there is an interface available for technology transfer through the equipment builder.

Reviewer 3:
The reviewer remarked that the project appeared to have excellent collaboration among project partners.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that the proposed future work is for the design and build of the prototype component and a production-scale welding system, which is to be accomplished during the remainder of the performance period. The milestones presented support a successful development of the end product. The reviewer noted that this project is mostly manufacturing development of technologies at a higher TRL where risk has been minimized previously during the advanced development phase.

Reviewer 2:
The reviewer recommended that it would be good to also have a real component testing planned rather than sticking to sub-component testing.

Reviewer 3:
The reviewer referenced prior comments related to understanding the sensitivities to necessary gap control and tolerances.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer remarked yes, the project indeed supports DOE objectives.

Reviewer 2:
The reviewer said this project supports an overall objective of DOE to improve fuel efficiencies in automobiles through using lightweight materials such as AHSS and Al. The current high cost of AHSS and the challenges in manufacturing automobile components when joining AHSS to Al prevent widespread use of these materials in the automotive industry. The reviewer detailed that this project addresses the barriers and challenges of joining these materials on a pre-production scale from an initial material selection, coupon testing, component manufacture and test, and final design and build of an automated welding system. The reviewer remarked that the testing is supported throughout with development and validation of a numerical model.

Reviewer 3:
The reviewer agreed that evaluating alternative solid state joining for lightweight material applications is certainly tied to program office objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer commented the team does have sufficient resources to accomplish the proposed objectives.

Reviewer 2:
The reviewer detailed that the performance period for this project is 4 years and has total funding of $2.7 million, which is almost $700,000 per year. Because the project involves mostly prototype manufacturing and testing, the resources for the seven partners are sufficient to produce the desired results.

Reviewer 3:
The reviewer remarked sufficient resources appear to be deployed.

Presentation Number: mat133
Presentation Title: Corrosion Protection and Dissimilar Material Joining for Next-Generation Lightweight Vehicles
Principal Investigator: D.J. Spinella (Arconic)

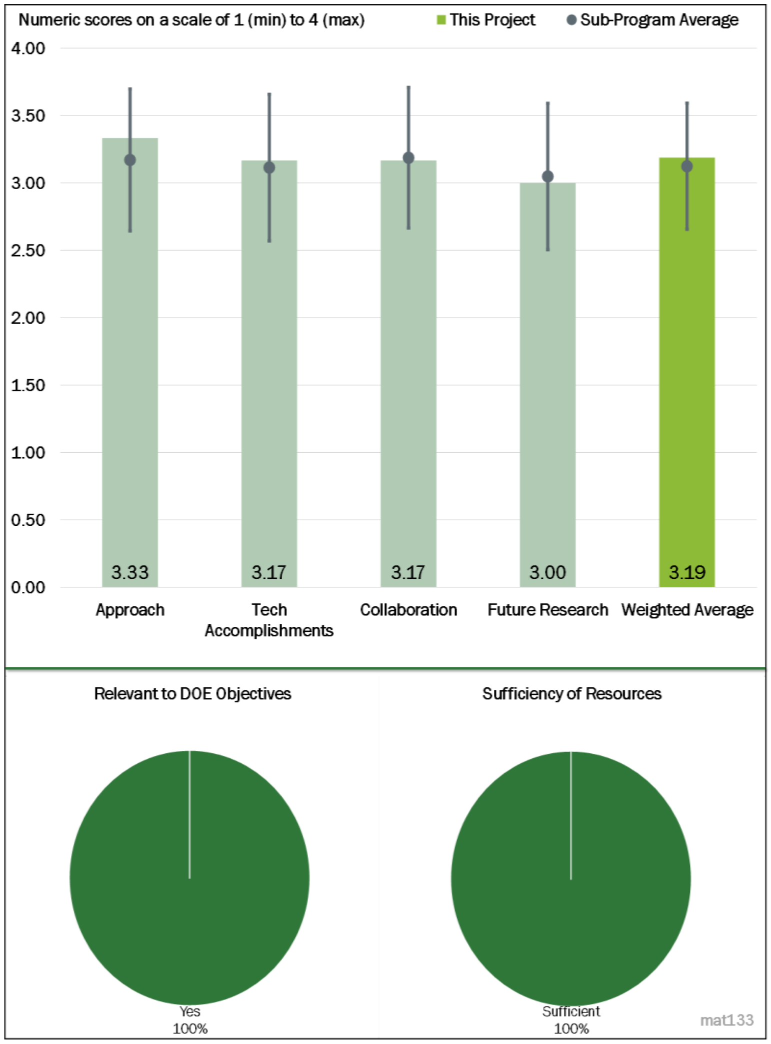

Figure 6-21 - Presentation Number: mat133 Presentation Title: Corrosion Protection and Dissimilar Material Joining for Next-Generation Lightweight Vehicles Principal Investigator: D.J. Spinella (Arconic)

Presenter
DJ Spinella, Arconic

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer said that the work described is well laid out, and clearly focuses on first providing definition of a specific class of technologies, establishing processing requirements, and finally testing the resulting components. Testing across a number of the partners is a plus. The reviewer said that a better interpretation of the process physics and metallurgy would be beneficial.

Reviewer 2:
The reviewer commented good approach, a high-volume application is the vision.

Reviewer 3:
The reviewer said that the approach is very comprehensive, which covers the related testing, from process developments for different material combinations, mechanical strength analysis, corrosion testing, and comparisons with base joining techniques, to demonstration in automotive manufacturer. The reviewer observed that it might be challenging to use a resistance spot riveting method to join long-fiber CFCs because the long fibers are difficult to cut through by rivet or machining.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that the team has accomplished the proposed tasks completely in the first budget period, and partially for the second budget period. The reviewer found that overall, the project is managed under a well-designed timeline and follows well for the go/no-go strategy.

Reviewer 2:
The reviewer remarked good progress to date.

Reviewer 3:
The reviewer said that the project appears to be slightly behind schedule. The reviewer saw no reason, however, that this project cannot catch up and complete within the allotted time.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer remarked the collaboration between Arconic as both a fastener supplier as well as a process technology developer, The Ohio State University for high-level corrosion expertise, and Honda as an OEM designer and implementer appears to be ideal. The reviewer found that this should provide continuity from understanding and mitigating any corrosion issues to fully equipped systems and rivet provider to a final product implementer.

Reviewer 2:
The reviewer remarked that the team is well-formed, where each partner contributes their unique expertise to the project. The assignments are clear between the partners/collaborators. The reviewer said that for the first year of the project, it seems most contributions are from Arconic, Inc. and The Ohio State University, which is determined by the nature of proposed work. The reviewer remarked more collaborations could be seen along with the project development.

Reviewer 3:
The reviewer recommended that increased collaboration is needed. The university and OEM seem to be working independently versus collaboratively.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer found, to be honest, the risk factors for future research appear to be relatively low. The processes have been demonstrated and the initial corrosion results appear to be attractive. The reviewer said it appears that the remaining work will largely provide data allowing future implementation of the technology.

Reviewer 2:
The reviewer said that the future research is comprehensive and aligns well with the proposed milestones. The proposed work should have addressed the challenges and barriers. The reviewer pointed out that the link between remaining challenges/barriers (Slide 18) and proposed future research (Slide 19) somehow is missing in the author’s slides.

Reviewer 3:
The reviewer remarked future research regarding qualitative corrosion test results need to be included. The reviewer said “as good as” is an opinion, not a qualitative research finding.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that the project is one of many steps necessary to enable true multi-material vehicles (particularly incorporating CFRP’s) into high-volume production.

Reviewer 2:
The reviewer said yes and elaborated that the corrosion in dissimilar material joints is a critical issue and can hinter their applications in many industries, especially in transportation sector. The reviewer pointed out it is also well-known that the dissimilar material joints can save the weight of structure, improve fuel efficiency, and reduce air pollutions. Thus, the reviewer found that this project supports the overall DOE objectives.

Reviewer 3:
The reviewer noted that joining technologies are very relevant to multilateral vehicle construction to achieve mass reduction objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the team has sufficient facilities, expertise, and human resources to achieve the stated milestones.

Reviewer 2:
The reviewer remarked resources seem sufficient.

Reviewer 3:
The reviewer said that the team appears well-equipped to complete the stated objectives within the program timeline.

Presentation Number: mat134
Presentation Title: Assembly of Dissimilar Aluminum Alloys for Automotive Applications
Principal Investigator: Piyush Upadhyay (Pacific Northwest National Laboratory)

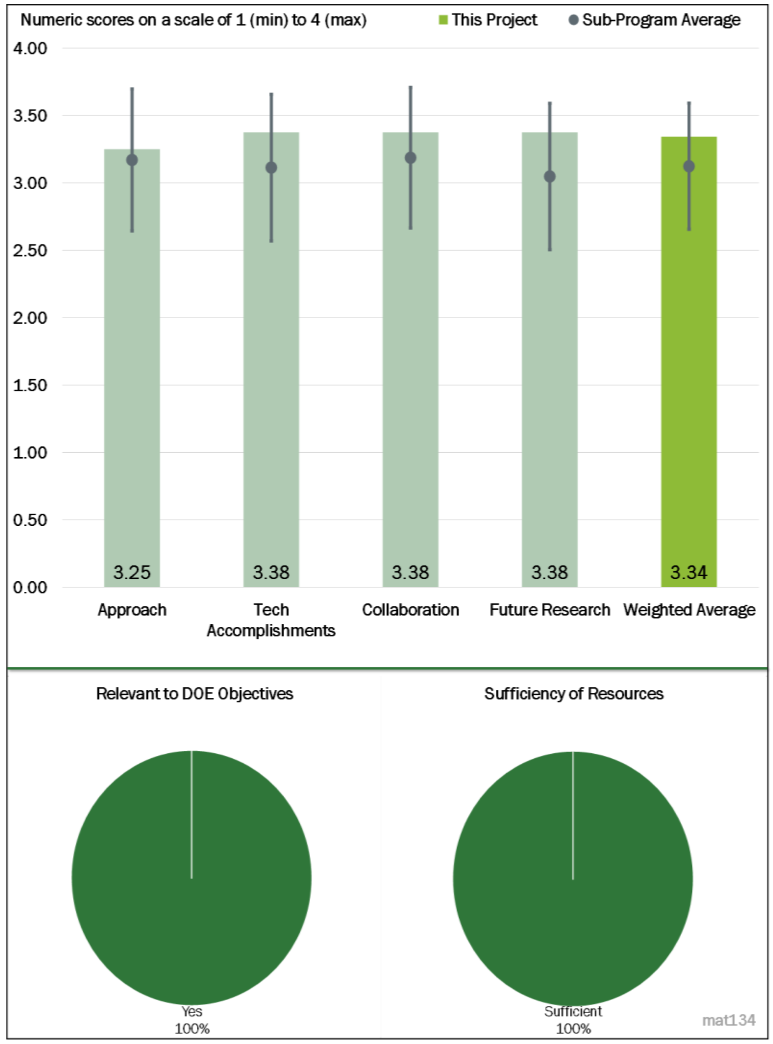

Figure 6-22 - Presentation Number: mat134 Presentation Title: Assembly of Dissimilar Aluminum Alloys for Automotive Applications Principal Investigator: Piyush Upadhyay (Pacific Northwest National Laboratory)

Presenter
Piyush Upadhyay, Pacific Northwest National Laboratory

Reviewer Sample Size
A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer observed that a very thorough approach was presented for the technical barriers to be addressed.

Reviewer 2:
The reviewer said good approach and recommended that the project team consider a future robotic application.

Reviewer 3:
The reviewer acknowledged that the approach is good, but the comparison to a baseline metal is not convincing and should be addressed by comparing it with other joining methods.

Reviewer 4:
The reviewer referred to a response given in question four. The reviewer asked what the effect is of welding more than half the thickness of the middle layer. This approach not discussed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer was very pleased to see the sensitivity studies on the effects of weld parameters on joint strength.

Reviewer 2:
The reviewer remarked very good progress, the project design is robust.

Reviewer 3:

The reviewer said that the presented accomplishments are good, but as noted, the baseline comparison should be changed. The reviewer also suggested that a more fundamental basis could be provided of why the observed behavior is happening so that this hypothesis can be expanded for further development and application.

Reviewer 4:

The reviewer said that there was not enough discussion on the observed defects so far. The defects have been described well, but discussion could be improved. The reviewer referenced Slide 11 and asked why there is a dip at around 2 m/minute. The reviewer asked what the effect is of welding more than half the thickness of the middle layer, and does it make sense to use as “baseline” the bead on plate weld rather than the base metal as is being done currently. Regarding Slide 13, the reviewer said it was not obvious that the increased hardness arising out of larger welding speed will result in increased joint strength. It would have been nice to have evidence of the same. The reviewer remarked that, as a matter of fact, on Slide 14 the data suggest the opposite. Unless the reviewer is missing something, in the first two rows, the only difference is in speed, but strength is lower at higher speed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that collaboration appears sufficient to support project objectives.

Reviewer 2:

The reviewer remarked good collaboration between the team members.

Reviewer 3:

The reviewer said it seems to be very good collaboration between the OEM and PNNL, and Arconic is supplying materials and ensuring practical application.

Reviewer 4:

The reviewer noted that conference calls were mentioned, and the reviewer hoped there were also at least a few face-to-face meetings

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer said that an outline of key activities for future research is very much in line with project requirements.

Reviewer 2:

The reviewer remarked good plan going forward.

Reviewer 3:

The reviewer referenced prior comments that the baseline comparison should be changed and addressed.

Reviewer 4:

The reviewer said that challenges were well-described and captured. The reviewer did not realize until Slide 18 that there had been no integration of the third Al outer layer into the FSW joint. The reviewer inquired if everything reported is for two layers only.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that the project directly impacts the knowledge base associated with joining of dissimilar materials.

Reviewer 2:
The reviewer noted how FSW is a significant pillar of future multimaterial joining applications—specifically various grades of Al (5xxx/6xxx/7xxx) and Mg.

Reviewer 3:
The reviewer agreed that the project is relevant to DOE objectives.

Reviewer 4:
The reviewer said that there is a need to be able to use different materials, Al alloys in this case, for lightweighting, as well as to be able to manufacture them rapidly in production.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the project appears to use sufficient resources to support program.

Reviewer 2:
The reviewer remarked the project has sufficient resources.

Reviewer 3:
The reviewer commented resources seem sufficient.

Reviewer 4:
The reviewer said that no data have been presented to indicate that resources are insufficient. The reviewer acknowledged that it is certainly a challenging project with a number of key barriers left, so allotted funds are fully needed.

Presentation Number: mat135
Presentation Title: Technology Validation of Innovative Dissimilar Materials Joining Method in Automotive Production Environment
Principal Investigator: Zhili Feng (Oak Ridge National Laboratory)

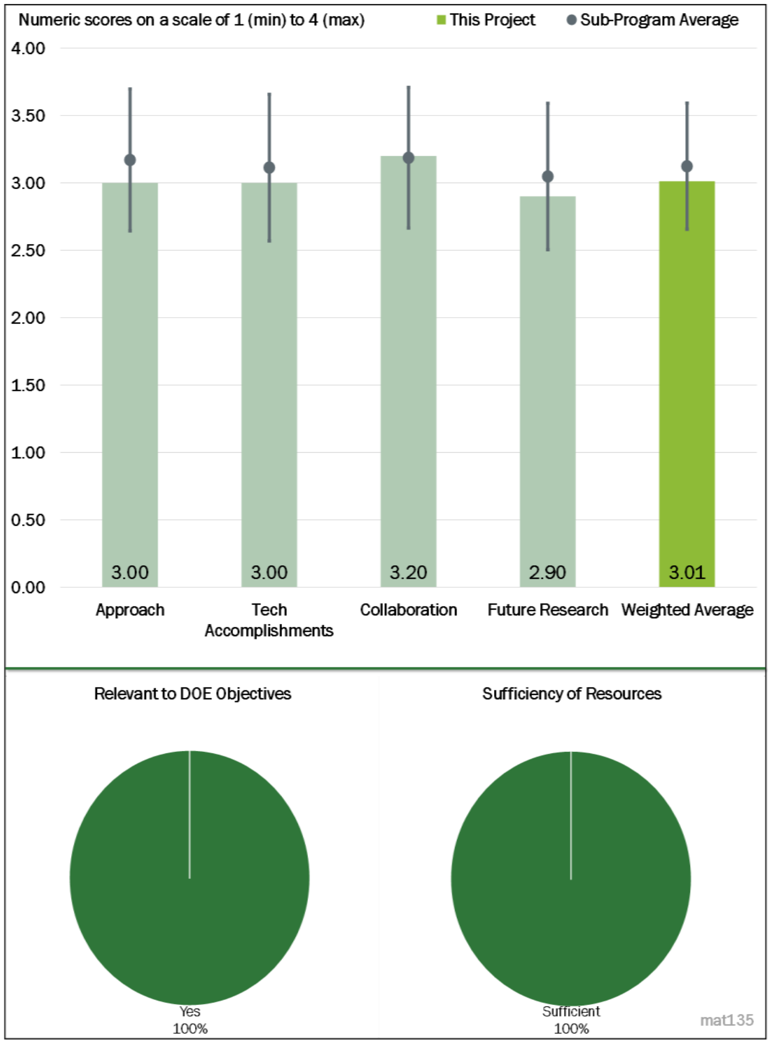

Figure 6-23 - Presentation Number: mat135 Presentation Title: Technology Validation of Innovative Dissimilar Materials Joining Method in Automotive Production Environment Principal Investigator: Zhili Feng (Oak Ridge National Laboratory)

Presenter

Zhili Feng, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that this project is very new. It relies on an older project that the reviewer assumed was successful. The project team is trying to scale up the project from coupon level to sub frame. The reviewer noted that the team has identified a part and have reached a specification for manufacture. At this stage, this seems to be a good plan.

Reviewer 2:

The reviewer remarked that this is a relatively fresh start with 10% completion, but direct pull from a manufacturing operation is a major victory.

Reviewer 3:

The reviewer pointed out that an advantage over a simple drill/rivet operation is not entirely clear, as the bit seems to be a reasonably costly component to sacrifice with each joint. The protrusion of the friction bit joining (FBJ) joint also seems problematic. The reviewer remarked that more background on this would have been helpful. The reviewer noted that a comparison of the lap shear strength with other methods is a critical introductory piece of information, but the project's presentation of this result was rather inadequate. With all of the factors that are relevant to actual joint strength, a straight-line comparison of joint shear strength (reported as a non-normalized force—kN) provides no useful information whatsoever. The reviewer acknowledged having to excuse the project at this point as the work is still early and there appears to be motivated participation from other team members that would indicate the potential value of the process.

The reviewer observed that reporting the bond strength between the bit and the steel substrate is also not overly convincing as to the advantages of the process. The reviewer asked why a relatively high-quality joint from a friction weld between metallic materials would not be expected. The key to this process is the durability of the CFRP or other laminated fiber layer following a rather destructive insertion of a rotating bit. The reviewer noted how the presenter pointed out the necessity of analyzing this quality, but the joint analysis thus far seems to be exactly what would be expected. The reviewer noted how C content in the weld joint due to the CFRP drilling at the tip of the bit may be one item of concern and will also require more detailed analysis.

Reviewer 4:

The one suggestion that the reviewer requested the project team to consider is benchmarking the proposed FBJ versus other known joining methods for the same substrates used in the project. Much discussion was focused on Slide 7; however, there was no basis of comparing FBJ to the other references. The reviewer asked whether FBJ would still show close to two times the performance improvement if the same substrates were used for joining methods in reference 8 and 9. The reviewer also pointed out that the project plan did not specifically mention when the adhesive combination would be evaluated.

Reviewer 5:

The reviewer remarked that the approach is good but it would be good to see more insights into the joint strength comparison to other dissimilar joining methods, interfacial characteristics, issues with CFRP cracking, etc. The approach seems more focused on implementation without addressing or investigating fundamental issues for widespread application of this technology.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that at this early stage in identifying a part, identifying the specifications of the cell is a good accomplishment.

Reviewer 2:

The reviewer remarked overall, a good start, and detailed that there is key work to be completed, but the parallel paths between process optimization and industrial scale-up seem well crafted. The reviewer cited how the milestones list strongly suggests that the process is now optimized and ready for deployment pending appropriate scale-up trials. The reviewer asked if there are missing data or past work that would qualify this. The testing completed thus far indicates that a milestone or two that evaluates a matrix of process approaches (such as bit geometries or materials systems) would be prudent.

Reviewer 3:

The reviewer noted that much of the technical accomplishments were focused on FBJ. The reviewer asked if the hat sections made will be used for destructive tests. The reviewer suggested the project team please incorporate the evaluation of the hat-section into the project plan.

Reviewer 4:

The reviewer said that the accomplishments are catered to the objectives proposed but lack in providing any advancement in science for broader application of the proposed technology. The reviewer said that a fair comparison to other popular joining methods, tested at similar conditions, would be very helpful.

Reviewer 5:

The reviewer pointed out that it is difficult to access the technical progress without application detail. The application material set needs to be disclosed. The application may be confidential, but public disclosure of the material set is critical.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that the project appears to have sufficient collaboration among members.

Reviewer 2:

The reviewer said good collaboration between team members.

Reviewer 3:

The reviewer reiterated that at this early stage in the project, the team has agreed to a part and has designed a manufacturing cell.

Reviewer 4:

The reviewer said that the program has a good mix of collaborators that provide confidence in the level of motivation behind the work. The reviewer remarked that while it is a novel approach to joining, to the untrained eye it would seem that the structure and protrusions from the joint would be factors that limit interest. The collaboration team (producers/OEM) indicate otherwise.

Reviewer 5:

The reviewer was unsure of the engagement of Hyundai, there was no mention of any interaction.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The future work really builds upon the success of the weld joints thus far—a topic that is arguable at this point based on the lack of useful mechanical property data. The reviewer asked what mechanical testing is planned—or what is relevant that has not been carried out. The reviewer remarked that the shear strength comparison hardly provides enough confirmation of the process.

Reviewer 2:

The reviewer suggested incorporating at coupon or hat-section component level the benchmarking against a few selected known joining techniques. The reviewer also suggested assessing the composite panel damage as a result of FBJ creating a hole. The reviewer pointed out that different composites may show higher sensitivities to damage initiated by drilling into a composite panel. The reviewer said that there needs to be some sort activity that better evaluates the interaction of the composite particles in the joining area.

Reviewer 3:

The reviewer acknowledged that technology scale-up is the proposed future research, but suggested that highlighting any insights from other, prior issues would be helpful.

Reviewer 4:

The reviewer said that insufficient detail was provided to comment on proposed future research.

Reviewer 5:

The outlined future research that will build the cell and test parts will determine the viability of the process at the production level. However, the project team suggested that it will not carry out the corrosion testing. Corrosion could stop this method from going to production

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer pointed out that mixed material joining enables lighter-weight structures. This project is in this area.

Reviewer 2:

The reviewer remarked that the project is definitely relevant to the DOE objectives.

Reviewer 3:

The reviewer said that the project falls firmly into the multi-materials joining category; enabling the joining of dissimilar materials enhances the opportunity for lightweight materials to see increased utilization.

Reviewer 4:

The reviewer commented demonstration of joining CFRP to steel for automotive application needs.

Reviewer 5:

The reviewer said joining dissimilar materials using friction bit in a production application of dissimilar materials joining.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that there appears to be sufficient resources used.

Reviewer 2:

The reviewer found that the team has sufficient resources to implement the project.

Reviewer 3:

The reviewer said that resources seem sufficient

Reviewer 4:

The reviewer remarked that the team has shown that it was able to design a proper cell for manufacture.

Reviewer 5:

The reviewer acknowledged maybe missing something—and asked if all of the funding has been received. The slide shows $633,000 from both VTO and the cost share partner as the total program cost; that same amount was received in 2018. The project runs until 2020. The reviewer asked so is this a $1.3 million project or is it that much per year.

Presentation Number: mat136
Presentation Title: High-Performance Computing and High-Throughput Characterizations towards Interfaces-by-Design for Dissimilar Materials Joining
Principal Investigator: Xin Sun (Oak Ridge National Laboratory)

Presenter

Xin Sun, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the proposed approach is right on the path to address the observed technical barriers. There is considerable preliminary work conducted that lays a foundation for the proposed work. The reviewer said that the design of work is well established and seems feasible.

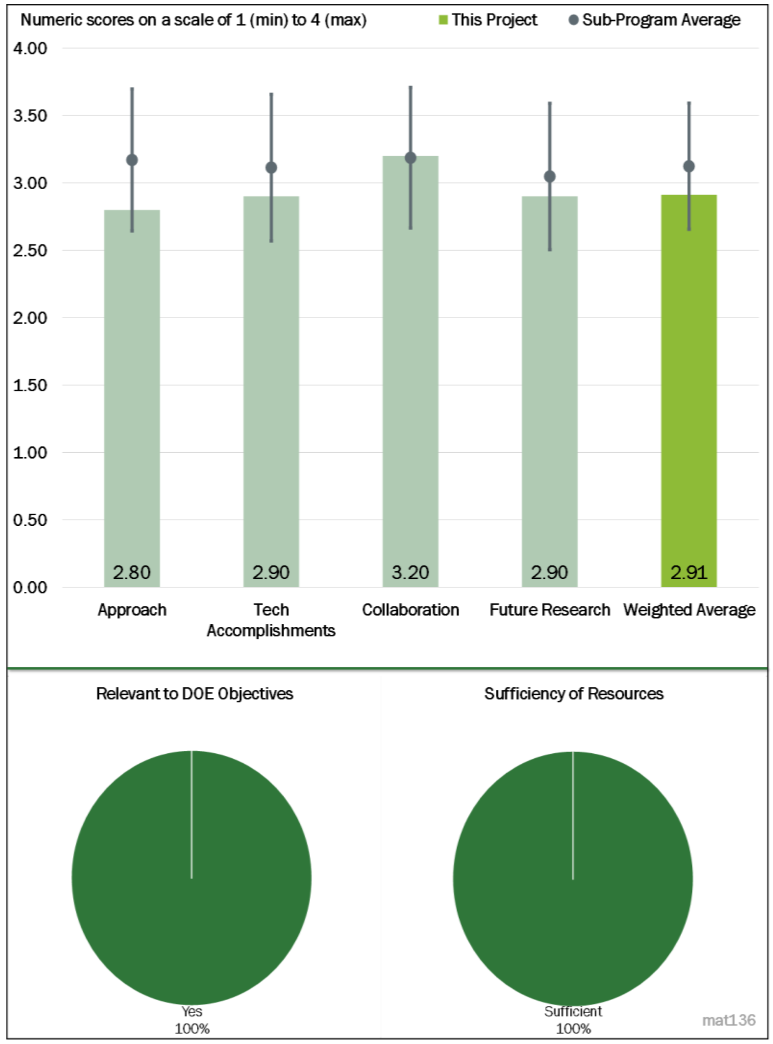

Figure 6-24 - Presentation Number: mat136 Presentation Title: High-Performance Computing and High-Throughput Characterizations towards Interfaces-by-Design for Dissimilar Materials Joining Principal Investigator: Xin Sun (Oak Ridge National Laboratory)

Reviewer 2:

The reviewer said that the inverse computational approach is effective to design the process by considering the joint performance, and maybe has less design cycle time compared to traditional computational approach. Also, the multiscale simulation will help explain the physics behind the process and bond formation.

Reviewer 3:

The reviewer remarked that perhaps this has been already addressed, but in the oral or the written presentation, the approach could have been better supported by showing the different phases of the project, how the different phases are tied to the project objectives, the other milestones, and the estimated timeline for studying the key parameters.

Reviewer 4:

This reviewer had trouble following the approach described as “Interface by Design.” The reviewer said that this sounds interesting in principle, but the presentation provided no evidence to support that this “reverse of ICME” can be done simply from data analytics. The reviewer hoped to see more of the “cross-cutting foundational element” demonstrated next year.

Reviewer 5:
The reviewer said that, unfortunately, the project is pretty ill-conceived. Statements such as, there are no proven joining methods for dissimilar materials, is just unfounded (think mechanical fasteners and adhesives), and even for metallurgical bonding (welding methods) many approaches have been in production for decades. Also, according to the reviewer the notion that there is no understanding of the mechanics of bonding for dissimilar metal welds belies 50 years (or more) of literature on the subject. The reviewer understands the project is in the early stages, but an extensive literature review is clearly in order.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer pointed out that the simulations of a few processes have been finished. The results are very interesting, presenting many phenomena that cannot be observed from direct experiments. The reviewer suggested presenting a progress chart, so reviewers could see how the progress goes in accordance with the proposed tasks.

Reviewer 2:
The reviewer said that work has largely jumped to applications pre-selected based on PNNL/ORNL experience (the reviewer inquired where the industrial input is). The reviewer said that the focus is supposed to be defining the interfacial science first, but most of the results are essentially process models and do not address the interfacial science of these joints.

Reviewer 3:
The reviewer failed to see key accomplishments regarding adhesive-based technology and surface morphologies.

Reviewer 4:
This reviewer observed a new project and no significant progress made yet.

Reviewer 5:
The reviewer reported that Slide 7 talks about a future technical accomplishment (“Temperature history will be utilized to perform diffusion and reaction calculations to predict interfacial chemistry and phase composition”). Ideally, these slides should only list the accomplishments that have already happened, and asked whether this was done on Slide 8. The reviewer acknowledged seeing the temperature contours, but was unclear if they have been used to perform diffusion and reaction impacts on the interface. For the two milestones listed on Slide 6, this reviewer inquired as to whether Milestone 1 led to Milestone 2, i.e., whether any data from Milestone 1 was used to establish Milestone 2.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said that the team is made up of an excellent group of researchers who seem to communicate and coordinate well.

Reviewer 2:
The reviewer noted that the team consists experts from different scales of summations, from molecular dynamics, to macro-scale finite element. Also, the experimental validation is included in the team.

Reviewer 3:
The reviewer said that it would have been great to see where the different expertise exists in the national laboratories and how they are being used to tackle the interface problem, i.e., adhesive interface, adhesive key properties, science of adhesion, etc.

Reviewer 4:
The reviewer said good collaboration between the team members.

Reviewer 5:
The reviewer said that collaborations are between two DOE national laboratories only, no other external collaborators to help "keep the peace." The reviewer pointed out that cooperative research and development agreements (CRADA) are in the plan ("will be pursued"), but the reviewer asked why not start it already. Generally speaking, interactions between DOE national laboratories tend to be minimal. The reviewer said that in this project, there was no overwhelming evidence to suggest that this is otherwise.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that it will be nice to differentiate the research challenges for FSW and ultrasonic welding because both are thermomechanical processes and share similarities.

Reviewer 2:
The future work references very high-level topics, it would have been beneficial to see a bit more specific details for supporting future work

Reviewer 3:
The reviewer acknowledged this is a new project, so no critical comments. However, as work is planned, it would be great to make a fair comparison on well-established theories in dissimilar material joining that has been done over the past 10 years.

Reviewer 4:
The reviewer said, basically, the rating is based on two bullet points on Slide 11 under "Future work." The reviewer said this project is a huge challenge with a big ambitious goal, and the reviewer hopes it turns out to be successful.

Reviewer 5:
The reviewer said that this project could use some serious structure. No real plan is laid out, with easily definable milestones and decision points. The reviewer remarked that this project has a "go big or go home" feel, and would be very difficult to manage. It is not clear to this reviewer what scientific paths the team will take to address the basic goals of modeling the interfacial science in order to evaluate\create next-generation process technologies.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer agreed highly relevant to DOE program objectives.

Reviewer 2:
The reviewer said that DOE has a significant interest in developing and validating new-generation dissimilar materials joining processes as a vehicle for creation of multi-material lightweight structures.

Reviewer 3:
The reviewer commented that dissimilar material joints can save the weight of structure, improve fuel efficiency, and reduce air pollutions. The simulation can reduce the experimental cost caused by trial and error.

Reviewer 4:
The reviewer remarked very scientific-based approach, much needed. The reviewer is very much looking forward to next year's AMR but perhaps a longer review session than 15 minutes.

Reviewer 5:
The reviewer said modeling and simulation, and using the same is very important, assuming that this interface by design concept can be made to work. The reviewer found that the barriers are well described.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer referenced a prior comment, and said that the project team here is highly qualified and competent. The problem is with the milestones and timing themselves. The reviewer found that resources here are considered excellent.

Reviewer 2:
The reviewer said that the team has sufficient facilities, expertise, and human resources to achieve the stated milestones.

Reviewer 3:
The reviewer commented that the team has requisite resources to conduct the project work.

Reviewer 4:
The reviewer said that after FY 2019 (Year 2), it may be worth to see if there is sufficient progress in Years 1 and 2 to continue into Year 3. Granted that this is only Year 1, but according to the reviewer progress seems somewhat limited.

Reviewer 5:
The reviewer was not very clear on efficiency of resource utilization as very little information was presented on a comprehensive project plan.

Presentation Number: mat137
Presentation Title: Adhesive Bonding of Carbon-Reinforced Plastic to Advanced High-Strength Steel
Principal Investigator: Amit Naskar (Oak Ridge National Laboratory)

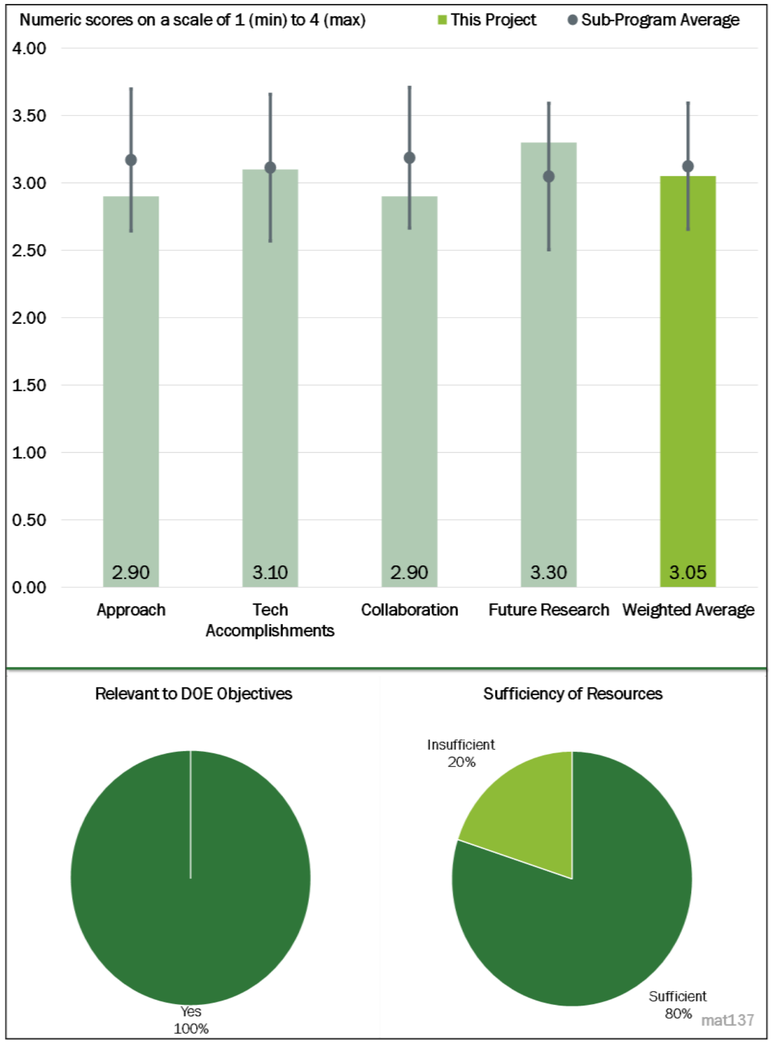

Figure 6-25 - Presentation Number: mat137 Presentation Title: Adhesive Bonding of Carbon-Reinforced Plastic to Advanced High-Strength Steel Principal Investigator: Amit Naskar (Oak Ridge National Laboratory)

Presenter

Amit Naskar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found that the overall approach is good. The reviewer expressed concern that there is considerable information in the literature on surface requirements for adhesive bonding to both metals and ceramics. A literature review to make sure that the existing knowledge base is covered and considered seems to be lacking. Also, according to the reviewer most adhesive formulations (and the associated chemistry) are extremely proprietary. This was questioned during the presentation, and no way to address this was discussed.

Reviewer 2:

The reviewer noted that the project is new. The approach is well laid-out but it would have been good to know what exact focus the project team is investigating because a lot of work was done in this field.

Reviewer 3:

The reviewer thought there could have been a much better job on articulating the approach. The approach presented is way too general, and not well tied to the overall project plan. The reviewer said it would be great that the project team can present the approach in such a way that is directly tied to the overall project objectives, and delivery against the identified project milestones. The reviewer did not characterize Slide 5 as a comprehensive project approach. Sorry, perhaps the time allocated to review the project was simply too short to better articulate the technical approach taken on the project.

Reviewer 4:

The reviewer said that the proposed approach is very comprehensive. The approaches listed on Slide 5 look confusing. Also, according to the reviewer there are many tests proposed, and it is not clear whether all the tests will be performed (e.g., the surface treatment). The adhesive formulation is controlled by the suppliers, which may raise the challenges in the surface improvement.

Reviewer 5:

The reviewer observed that while the Approach slide (Slide 5) brings out the complexity of the problem well, at the same time, it confuses and complicates the Approach that is being taken. Indeed, it is difficult to even say what the gist of the Technical Approach is. The reviewer said that perhaps the purpose would have been well-served if only some arrows were used to focus on what is being done precisely in this project. The reviewer said that the PI failed to explain the approach clearly and how it would attack the barriers, namely how to join metals to composites.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviver said that the project started this year and is productive considering the given time period.

Reviewer 2:

The reviewer noted that progress has been made, but key elements of knowledge-base capture and adhesive manufacturer coordination have not been addressed.

Reviewer 3:

The reviewer remarked it would have been great if the effect of curing temperature and time, or effect of chain mobility and adhesive bonding, was explained, and how the outputs support the project objectives or barriers. It appears that a bunch of experimental measurements were carried out and specific results reported but nothing else to link how the findings are linked together, how the findings are related to the project plan and objectives.

Reviewer 4:

The reviewer said that this is a new project and commented that prior work and planned outline are well-regarded. The reviewer advised it would be good to compare future results with those already in literature but tested at the same conditions.

Reviewer 5:

The reviewer remarked that the technical Accomplishments slides were somewhat disjointed, more like literature survey results, and very preliminary results on large differences in lap shear tests. The reviewer would have preferred to see more adhesives used on the same material combination, though the differences of the same (?) adhesive on the three material combinations is interesting. The reviewer asked if the digital image correlation (DIC) is being used to measure strain or only the qualitative nature of strains.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that it seems like a good collaboration will be facilitated in the project.

Reviewer 2:

The reviewer said that the collaboration between ORNL and PNNL will fully utilize their expertise and facilities. There are a few tasks indicating that both laboratories will provide the work; however, the role of each party is not very clear.

Reviewer 3:

The reviewer referred to prior comments, and said need to see better collaboration with the adhesive manufacturers.

Reviewer 4:
The reviewer said that there appears to be experimental work that is being completed, but the reviewer did believe there is sufficient interaction among project members to fully understand the significance of the project generated outputs.

Reviewer 5:
The reviewer remarked that it would be nice to see additional industry or academic partners in addition to just the DOE national laboratories. The reviewer did not see any mention of transitions to outside DOE to the automotive industry, for example.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer remarked that the outline for future proposed work is good.

Reviewer 2:
The reviewer said that moving forward, the approaches have merit. However, the background knowledge and manufacturer coordination issues need to be addressed.

Reviewer 3:
The reviewer commented that the work plan is good, but a comparison with the existing work and knowledge base is highly recommended.

Reviewer 4:
The reviewer remarked that the future work captures the research challenges in adhesive bonding of CFRP and metal. The health monitoring in service may take a longer time compared to the accelerated testing, and the one-year period for this task may not be enough.

Reviewer 5:
The reviewer said that the project has only just started, and the challenges are many. The term Interface by Design is used several times without clear explanation. The reviewer said that future proposed work (Slide 14) is really a set of objectives without detail, even in principle, on how to achieve them.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer pointed out that joining of lightweight materials is a foundation to many of the challenges associated with mixed materials.

Reviewer 2:
The reviewer pointed out that DOE has made integration of new materials a key element of VTO. An integration of composites creates focus for this type of work.

Reviewer 3:
The reviewer commented that the dissimilar material joints can save the weight of structure, improve fuel efficiency, and reduce air pollution. Adhesive bonding has been proved an effective method to join CFRP with metals, especially the CF-reinforced thermoset composites.

Reviewer 4:
The reviewer said very relevant to the DOE program objectives.

Reviewer 5:

The reviewer commented that the project supports using dissimilar materials and how they are to be joined.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked the team has sufficient resources to investigate the proposed work plan.

Reviewer 2:

The reviewer remarked that the team has sufficient facilities, expertise, and human resources to achieve the stated milestones.

Reviewer 3:

The reviewer noted that no data were provided to indicate that resources are not sufficient. In projects like these, the objectives and research will be tailored to available funding.

Reviewer 4:

The reviewer exclaimed that the resources are certainly excellent.

Reviewer 5:

The reviewer said that the presented findings portray an image of insufficient use of resources.

Presentation Number: mat138
Presentation Title: Solid-State Joining of Magnesium Sheet to High-Strength Steel
Principal Investigator: Glenn Grant, Pacific Northwest National Laboratory

Presenter
Piyush Upadhyay, Pacific Northwest National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

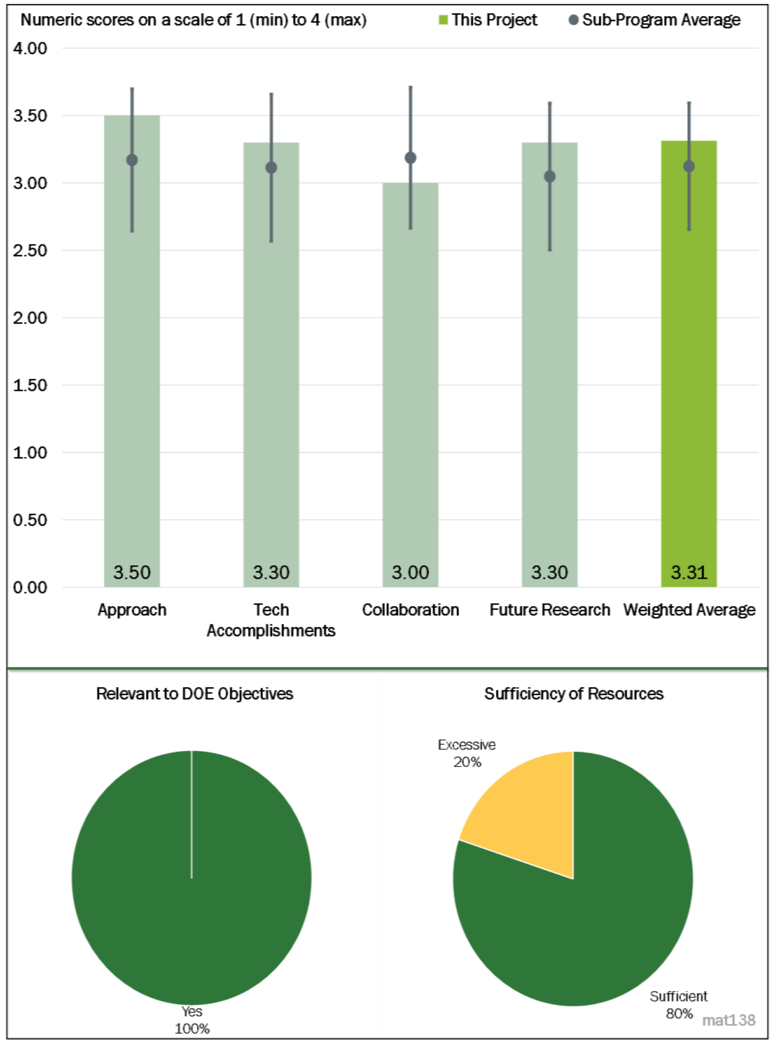

Figure 6-26 - Presentation Number: mat138 Presentation Title: Solid-State Joining of Magnesium Sheet to High-Strength Steel Principal Investigator: Glenn Grant, Pacific Northwest National Laboratory

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The approach is to use advanced techniques to characterize welds made using two different commercially-available methods: FSW and ultrasonic welding. Because these are well-known methods for similar materials, the challenge is to obtain a better understanding of the joining interface for dissimilar metals such as Mg and steel. The reviewer noted that the approach presented addresses joint fabrication, characterization, process data acquisition, fabrication under various conditions, and characterization and analysis of the joint interface. This reviewer found that the approach is sound for obtaining data to overcome some of the challenges of joining these two metals.

Reviewer 2:
The reviewer said that the proposed approach is very comprehensive. It is challenging to tailor the interface through friction stir or ultrasonic welding.

Reviewer 3:
The reviewer remarked that the PNNL team is leveraging and extending work on Al to steel for Mg. The reviewer thought that the approach to narrow it down to two technologies is sound and cost effective.

Reviewer 4:
The reviewer remarked that this is a fairly narrowly focused program addressing two defined technologies. The reviewer may question the technologies selected, but the approach is very good.

Reviewer 5:

The reviewer asked why Al to steel interface not was selected rather than Mg to steel, and whether the correlation of process parameters to interface chemistry is guaranteed, because it is more of an inverse problem. The reviewer inquired if the characterization methods are unique. Researchers do not want a relationship that works only in one specific case with no generality or applicability to another unknown set of parameters. This reviewer is not sure how the observed test behavior is being used by the modeling folks. The reviewer asked if it is a physics-based model that is being tweaked, or a data-fitting model.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The researchers have considerable up-front data allowing the team to formulate good approaches for interpreting performance.

Reviewer 2:

The reviewer pointed out that this is a new start project and is only 22% completed; however, there has been significant accomplishments made toward measuring the microscopic interface and bonding and interface heat generation for the ultrasonic welding process and the friction stir process. Characterization of an interfacial fracture mode has been determined for both methods and interfacial layers have been observed and characterized. The reviewer said that this performance shows great progress towards the objective for a broader understanding of joint interface.

Reviewer 3:

The reviewer noted that the project started this year and is productive considering the given time.

Reviewer 4:

The reviewer said that the project was initiated in 2018 so the majority of work has not been initiated.

Reviewer 5:

The reviewer pointed out that the project is in its early stages, and still establishing methods of measuring process variable. The reviewer detailed that a set of joints have been made for different conditions, but analysis still in progress. The reviewer said that it is difficult to judge if correlation or math modeling has been or will be successful.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that this is an internal DOE project team (PNNL/ORNL) and the team seems to be well-coordinated on this project.

Reviewer 2:

The collaboration between ORNL and PNNL will fully utilize their expertise and facilities. There are a few tasks indicating that the work will be performed by both national laboratories; however, the role of each party is not very clear.

Reviewer 3:

The reviewer noted that collaboration is limited to two national laboratories, PNNL and ORNL. The reviewer suggested that because the research addresses the science behind two commercial methods of joining, there project should also involve industry, either a Tier 1 supplier or an automobile manufacturer or both.

Reviewer 4:
The reviewer pointed out that while very early TRL, it would benefit the team to have two or more industry partners to help guide and establish the materials and performance targets.

Reviewer 5:
The reviewer said that like with other similar projects in this group, it would be nice to also see an industry or transition partner. Right now, it is just the two national laboratories. The dissemination process via papers is much more indirect than having direct partner with regular scheduled interactions.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer pointed out that this is a new-start project and much of the research is yet to be performed; however, the project is well planned and has a defined schedule of events. The proposed research is in line with the approach to meet the objectives and milestones for the remainder of the project. The reviewer said that alternate development pathways for mitigating risk are not necessary because this project is characterization of welds using commercial methods for dissimilar materials.

Reviewer 2:
The reviewer said that this project is relatively well-defined, and approaches are more focused on interpreting results than developing new methodologies. As a result, the future research approach is easy to describe and comes across as such in both the presentations and discussion.

Reviewer 3:
The reviewer observed that the future work addresses the important research challenges. The coupons for micro tensile test may not be small enough to test the interface mechanical properties. The reviewer pointed out that the joint interface is a complex structure, and it is important to ensure the results are presentative.

Reviewer 4:
It was very difficult for this reviewer to give many details because this was only a 15-minute presentation. The reviewer expected that the team will evaluate a number of failure modes, including TSS, CTS and/or t-peel, which would increase confidence in the process. Additionally, the reviewer said that there should be a stretch joint, i.e., considering Mg to a UHSS of at least 980 MPa.

Reviewer 5:
The reviewer indicated that challenges are somewhat “generic” as described. The reviewer noted that the presentation said, “There is a need to establish effective methods to obtain mechanical properties of interface region,” and expressed uncertainty about what that means, other than “currently we have no idea what to do.”

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer remarked that this project supports an overall DOE objective to improve fuel efficiencies in automobiles through the use of lightweight materials such as Mg and a dual-phase steel. The current high cost of Mg sheet metal and the challenges in manufacturing automobile components with dissimilar materials prevent widespread use of both materials in a single component in the automotive industry. The reviewer said that this project addresses the barriers and challenges of joining Mg to steel by further investigating and correlating process parameters and variables to the weld interface and properties to maximize material properties at the joint.

Reviewer 2:

The reviewer remarked the dissimilar material joints can save the weight of structure, improve fuel efficiency, and reduce air pollution. Mg and HSS are two important type of materials for lightweighting.

Reviewer 3:

The reviewer commented this meets the criteria of enabling lower-weight structures.

Reviewer 4:

The reviewer said that the project is only limited by the fact that neither of these technologies is likely to be exploited in any major way in vehicle construction.

Reviewer 5:

The reviewer asked if this (Mg to steel) is more relevant than Al to steel. The latter may be of more immediate importance and applicability to the auto industry.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented the coordinated team is well suited to complete the described scope of work.

Reviewer 2:

The reviewer said that the team has sufficient facilities, expertise, and human resources to achieve the stated milestones.

Reviewer 3:

The reviewer said, again, no data to suggest that resources are insufficient to meet program deliverables. The reviewer thought that this project might be under the category of fitting the project to existing funding.

Reviewer 4:

The reviewer remarked that while PNNL and ORNL can do all the joining work technically, the team would benefit from consultation with both OEM and materials industry partners.

Reviewer 5:

The reviewer pointed out that this is a 3-year project funded at a total cost of $1.7 million for only two performers, which is almost $600,000 per year or $300,000 per lab. Based on the information presented, the reviewer found that the cost appears to be a little excessive for the type of work (materials characterization) that is being performed.

Presentation Number: mat139
Presentation Title: Joining Magnesium Alloys to Carbon Fiber Reinforced Polymers
Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory)

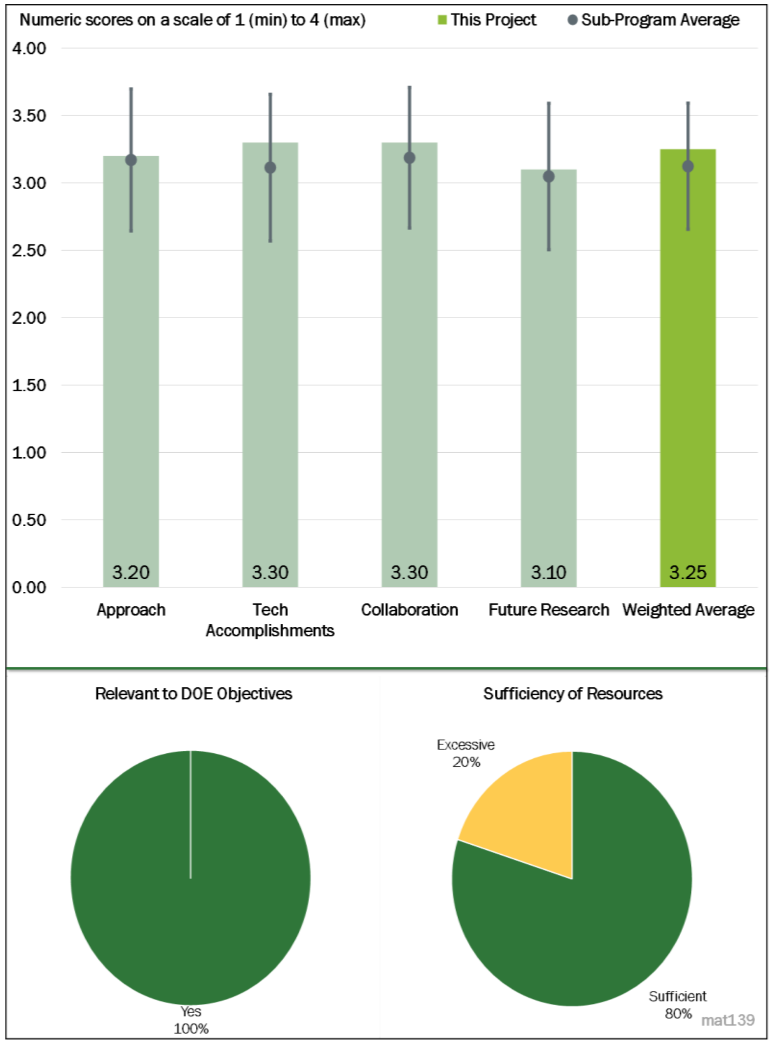

Figure 6-27 - Presentation Number: mat139 Presentation Title: Joining Magnesium Alloys to Carbon Fiber Reinforced Polymers Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory)

Presenter
Darrell Herling, Pacific Northwest National Laboratory

Reviewer Sample Size
A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:
The reviewer said that the approach addresses the investigation of four commercially available joining methods used mostly for similar materials, but this project focuses on two very dissimilar materials: CF and Mg. The project is well-designed and uses different approaches for each joining method to evaluate and overcome technical barriers to joining metals to composites and also issues of corrosion when these two materials are joined. The reviewer noted that the testing will only involve coupons of joined materials, and nothing was presented regarding component part testing or full-scale testing.

Reviewer 2:
The reviewer found that the proposed approach is very comprehensive. Predrilling holes could be changeling in the real production, especially to drill holes on long CF-reinforced polymer composites. The reviewer noted that the predrilled hole may cause corrosion because the moisture can go inside the holes.

Reviewer 3:
The reviewer pointed out that joining metals to composites is a big barrier, and the approach includes four different methods for down-selection.

Reviewer 4:
The reviewer commented this is an early TRL program with four different technologies being evaluated. Each technology would potentially have its own sweet spot so the reviewer was a little unclear on what defines success. The reviewer suggested the team have target applications and performances defined early to steer the right gauge combinations.

Reviewer 5:

The reviewer remarked the technology focus here seems to be on areas where ORNL and PNNL have some degree of expertise, rather than best approaches for the material combination. A major omission here is adhesive bonding. In addition, the reviewer did not see a difference in approach between thermoset and thermoplastic composites. In the latter case, localized plastic melting has been well-used as a metals-to-composites joining process.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer pointed out that this is a new-start project and it is in the early stages of execution. Consequently, minimal technical accomplishments were presented. The reviewer identified as the most-notable accomplishments that proof of concept and lessons learned have been identified, tensile strength for joints by bolting and FBJ have been characterized, influence of surface coatings have been evaluated, and the design of surfaces features that improve joint strength have been assessed using modeling and simulation.

Reviewer 2:

The reviewer said that good progress has been reported for all four methods with promising emerging results. The reviewer cited a patent application for friction stir interlocking and said that this is a good indication of technical progress and accomplishment.

Reviewer 3:

The reviewer pointed out that to date, progress has focused on understanding/describing the candidate technologies, so any judgement is premature.

Reviewer 4:

The reviewer noted that the project just initiated in 2018 so the majority of work has not been initiated.

Reviewer 5:

The reviewer noted that the project started this year and the team is productive by considering the given time period. It is unclear why the team reported the Al results (Slide 7) because the project focuses on Mg and CFRP.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer observed a solid technical team with both ORNL and PNNL working with industry suppliers.

Reviewer 2:

The reviewer observed that the collaboration between ORNL and PNNL will fully utilize their expertise and facilities.

Reviewer 3:

The reviewer thought it was good to see industry partners already part of the project, not just PNNL and ORNL as in a couple of other similar projects.

Reviewer 4:

The reviewer pointed out that collaboration involves two national laboratories and two material suppliers: one for the composite and one for the metal. Because this study is investigating the characterization of dissimilar materials joining for four commercially-available methods, the reviewer believed collaboration could be improved if a Tier 1 parts supplier or an automobile manufacturer, or both, were involved in the early design of experiments.

Reviewer 5:

The reviewer said that partners at ORNL and PNNL seem to be well coordinated. The reviewer asked where the industrial partnerships are. The reviewer pointed out that considerable work in this regard has been done by a range of OEM's and Tier 1's.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer pointed out that this is a new-start project and there is still much work to be done. The proposed future work includes down-selecting joining technologies, maturing those technologies, and incorporating corrosion barrier materials for the down-selected technology(ies). The reviewer noted that no details or milestones were presented to the degree of planning or the decision points that will be used to determine if the results will be successful or will need alternate characterization techniques.

Reviewer 2:

The reviewer said that some research has been done to join Mg with CFRP using ultrasonic welding or friction stir method, which could provide the information to speed up the process down-selection.

Reviewer 3:

The reviewer said that the project's overall direction is very promising. The team would benefit by narrowing the applications in each of the four technology areas to better define the performance requirements and joint specimen types. The reviewer expressed concern that the work shown was on on-lap shear specimen types. Additional work needs to address other failure modes such as cross tension and peel. Additionally, according to the reviewer the impact of adhesives and lubricants used in a production environment should at least be screened.

Reviewer 4:

The reviewer commented, as previously mentioned, this is pretty much a top-down type of project. The candidate technologies have been selected without any real interpretation of the application need nor of the bi-material science implied. This is less science and more technology evaluation, and the reviewer cautioned that the project could conceivably fail to yield any effective solution.

Reviewer 5:

The reviewer asked why FBJ, which was described in another project, not considered here, and if it can be included.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer commented that this project supports an overall objective of DOE to improve fuel efficiencies in automobiles through using lightweight materials such as Mg and CF-reinforced polymers. The current high-cost of Mg sheet metal and the challenges in manufacturing automobile components using a combination of metals and non-metals joined together prevent widespread use in the automotive industry. The reviewer remarked this project addresses the barriers and challenges of joining Mg sheet and CF-reinforced polymers by evaluating four different joining methods.

Reviewer 2:

The reviewer agreed yes, it does, and commented that DOE has long focused on integrating composite solutions into lightweight vehicle designs, so the work described here is pretty mainstream for that path.

Reviewer 3:
The reviewer commented that the dissimilar material joints can save the weight of structure, improve fuel efficiency, and reduce air pollution. Mg and CFRP are two important type of materials for lightweighting.

Reviewer 4:
The reviewer stressed that it is absolutely relevant to look at any multi-material joining technologies. The reviewer's only question is why not consider Al to CFRP.

Reviewer 5:
The reviewer was not clear about relevance, although the reviewer assumed that success is finding acceptable performance and cost for at least one of the four technologies being evaluated. If that is the case, then this would be in line with DOE goals to reduce weight and improve fuel efficiency.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that the team has sufficient facilities, expertise, and human resources to achieve the stated milestones.

Reviewer 2:
The reviewer commented team has both the right technical expertise and adequate resources.

Reviewer 3:
The reviewer said that no data were provided to suggest otherwise.

Reviewer 4:
The reviewer said that the project seems to focus specifically on technologies where the DOE national laboratories maintain a high-level of expertise, providing sufficient resources for the project's needs.

Reviewer 5:
This project is a 3-year project for $1.8 million with only two performers: PNNL and ORNL obtaining materials from two commercial sources, which is $300,000 per national laboratory. According to the reviewer, this seems somewhat excessive because the project will be evaluating four commercial joining methods, down-selecting to one or two methods, and characterizing the joints from a materials perspective (mechanical properties and corrosion effects). The reviewer remarked that the presenter and presentation does not address component part testing or full-scale testing where the project costs are typically higher and would be in the $2 million per year range.

Presentation Number: mat142
Presentation Title: Metal Matrix Composite Brakes Using Titanium Diboride
Principal Investigator: Glenn Grant, Pacific Northwest National Laboratory

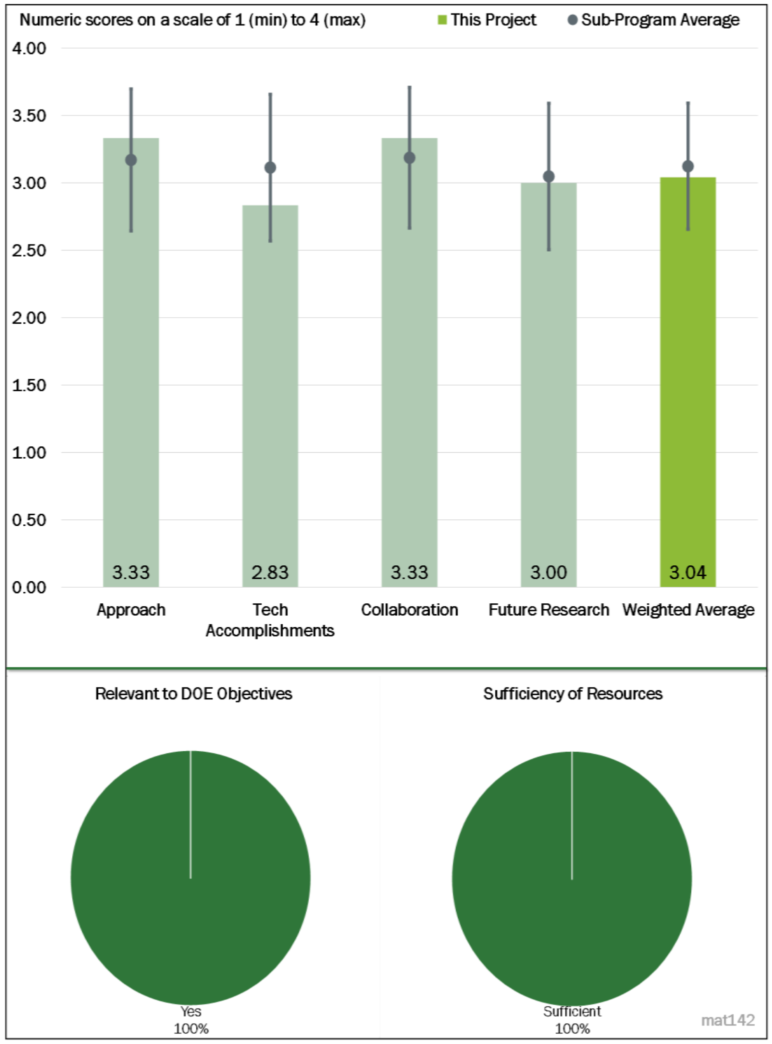

Figure 6-28 - Presentation Number: mat142 Presentation Title: Metal Matrix Composite Brakes Using Titanium Diboride Principal Investigator: Glenn Grant, Pacific Northwest National Laboratory

Presenter

Glenn Grant, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that titanium diboride (TiB_2) could be a good reinforcement.

Reviewer 2:

The reviewer said that the approach is well-defined and the objectives are clear—the widespread use of metal-matrix composites (MMCs), despite their plethora of positive attributes for certain applications, remains massively limited due to material/processing/productions costs. Rotors for brakes are both the obvious choice (due to weight savings and wear resistance) and a difficult component to replace (due to the ability to replace cast iron rotors as a consumable at ~$25-$50 per part on the aftermarket). The reviewer found that the approach to re-classify brakes as a "life-of-the-vehicle" component is compelling.

The reviewer detailed that leveraging existing DOE databases from work that was done decades ago is a positive reflection on this program—and clearly shows the value of projects that collect and organize data that can be utilized as a later date. The reviewer remarked it would have been unsurprising for a program like this to suggest that the project team will run extensive testing to baseline known materials, but the team is able to utilize information that already provides that baseline. The reviewer remarked the PNNL role is not overly advanced (nor does it need to be) as the industrial partner is providing a large fraction of the necessary work in material and component production. PNNL has established expertise in the casting/machining that they will be performing. Additionally, according to the reviewer the ability for PNNL to appropriately validate the performance provides a very large level of credibility to any results that are obtained.

Reviewer 3:

The reviewer said that there was no information on the TiB_2 MMC manufacturing process, and there was no discussion about the challenges of getting the desired composition and manufacturing process for optimum brake material manufacture. There are no cost analyses and no unit cost for the TiB_2 brake discs. However, the reviewer noted that the PIs informed the audience that the task is planned but that data are yet to come. The reviewer said that baselining the TiB_2 MMC brake discs (durability, cost effectiveness, durability, etc.) should be carried out using the discs the project team is going to replace, i.e., the cast iron brakes. The value proposition of these new brake discs has to be well defined and explained with supporting data. The reviewer said that the testing is relatively straightforward, so the approach is good. The details of what is to be carried must be well thought out.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that the project started recently.

Reviewer 2:

The reviewer said that the project is still in the raw material production phase, so the technical accomplishments that will be of the most interest to reviewers (or followers of the project) are still upcoming.

Reviewer 3:

The reviewer noted that work is still relatively in its early stages so not many accomplishments apart from raw material processing, tooling, sorting out of some process parameters, etc. However, data should have been presented on the raw material production.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked good collaboration.

Reviewer 2:

The reviewer observed a great leveraging of a motivated industrial partner and a DOE national laboratory—with additional utilization of the LightMAT capabilities. The reviewer pointed out that the program lead is clearly an asset in vehicle-based programs as his practical knowledge of automobiles seems to be as extensive as his materials science knowledge.

Reviewer 3:

The reviewer pointed out that there is only one partner, an industry partner, Arconic. The distribution of tasks seems to be reasonable.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted that the “meat” of the program is still upcoming, specifically regarding the extensive testing that is planned. How the results will feed back to the manufacturing/production process to provide optimization parameters may also be part of the program, but according to the reviewer the real value will come when the performance measurables are presented.

Reviewer 2:
The reviewer pointed out that the entire work scope, except for Task 1, was presented as future work, which confirms that work is still in the early stages. However, the proposed future work seems reasonable. The reviewer noted that no task was called out for cost analyses (and value proposition assessment) though. The reviewer asked if this task has been lumped together with analyses and reporting.

Reviewer 3:
The reviewer said that a 0.25 mile per gallon improvement may not justify the added cost.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said that performance enhancement is important.

Reviewer 2:
The reviewer said that the project enables lightweighting of a particular component through materials development and selection. The reviewer noted that the project did an excellent job providing specific energy saving opportunity figures.

Reviewer 3:
The reviewer acknowledged that this question is a tough one. The reviewer wondered if the team is trying to fix an issue that is not really broken or a problem, or whether there is the right value proposition for the discs. The brake disc target weight reduction is 50% compared with steel brakes, so there is a weight reduction advantage (but that remains to be seen). However, the reviewer asked at what cost will these discs be produced. Therefore, cost analyses need to be carried out before this question is fully addressed. The reviewer also pointed out that lifetime durability seems to be the desired target so as to make the value proposition more attractive. The reviewer said that the durability level achieved remains to be seen as well. The value proposition seems to be targeted at electric vehicles (EV) and hybrid cars, so according to the reviewer a value proposition analyses has to take this into consideration; making sure that estimates take into consideration the total number of cars on the roads versus the target market, EV/hybrid cars, and hence overall impact of the new material and discs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that there seems to be no issue at this time with resources.

Reviewer 2:
The reviewer remarked sufficient resources.

Reviewer 3:
The reviewer found that the resources are adequate—it is not a large project and is more heavily subsidized by the industrial partner than most projects.

Presentation Number: mat143
Presentation Title: Mitigating Corrosion in Magnesium Sheet in Conjunction with a Sheet-Joining Method that Satisfies Structural Requirements within Subassemblies
Principal Investigator: Aashish Rohatgi (Pacific Northwest National Laboratory)

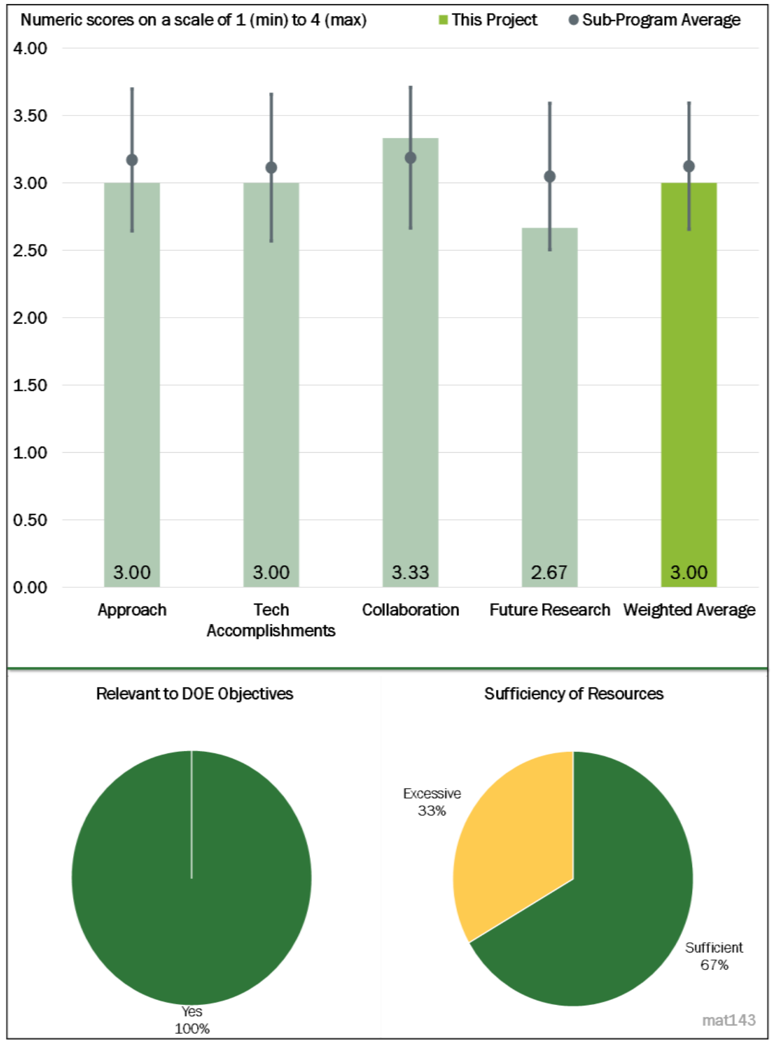

Figure 6-29 - Presentation Number: mat143 Presentation Title: Mitigating Corrosion in Magnesium Sheet in Conjunction with a Sheet-Joining Method that Satisfies Structural Requirements within Subassemblies Principal Investigator: Aashish Rohatgi (Pacific Northwest National Laboratory)

Presenter

Aashish Rohatgi, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the proposed approach is very comprehensive. According to the reviewer, it might be nicer to consider how to make the corrosion testing consistent, so that it can better explain the results. Currently, it is found the different angles or the locations of the samples will influence the corrosion results.

Reviewer 2:

The reviewer commented that the project is basically a testing project, with no technology development. The reviewer pointed out that Magna is selecting test materials based on their needs, and asked if PNNL is nothing more than a testing lab.

Reviewer 3:

The reviewer did not see this project as providing any solutions, just documentation on the current state-of-the-art. The reviewer acknowledged that corrosion testing of base materials as well as those with simple joints (impulse welds, and mechanical fasteners) will provide data on current corrosion performance, but what kinds of mitigating solutions is the project investing.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

By looking at task/milestone summary on Slide 5, it seemed to this reviewer that an acceleration may be needed to catch up the proposed tasks for this 2-year project.

Reviewer 2:
The reviewer said that the target here is pretty low. Because the researchers will only be corrosion-testing dissimilar material joints with standard assembly processes, progress is made by simply being able to set up an experimental system.

Reviewer 3:
The reviewer noted no major technical accomplishments, but the bar is somewhat low. The corrosion measurement techniques demonstrated in this project do not challenge PNNL's capabilities much beyond that of a test lab.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer said that because the work is largely driven out of Magna, the reviewer is not surprised that teaming has been effective.

Reviewer 2:
The reviewer thought that it will be nice to give more information on "various Tier-1 Suppliers."

Reviewer 3:
The reviewer reiterated that not much collaboration is required for such a relatively straightforward technical effort.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that microstructures are non-uniform for the dissimilar materials with proposed joining methods. The structure of the bonding interface could be very complicated. These could raise challenges in the investigating effects of microstructures on the corrosion performance. The reviewer pointed out that other factors, such as joint geometry, configuration, and residual stresses, could influence the corrosion behavior.

Reviewer 2:
The reviewer said that testing will answer whatever is currently "unknown." This reviewer is not sure if this is the best use of LightMAT funds.

Reviewer 3:
The reviewer reiterated that this is largely a testing program. The reviewer expressed being challenged by the notion that this project will overcome any barriers. At best, the project will assess potential corrosion benefits associated with contacting surfaces (e.g., joining with mechanical fasteners) and true metallurgical bonds. The reviewer struggled to see what the researchers are trying to achieve beyond this.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer pointed out that corrosion is one of the long-standing make or break questions in a multi-material-vehicle strategy.

Reviewer 2:
The reviewer commented that the dissimilar material joints can save the weight of structure, improve fuel efficiency, and reduce air pollution. Corrosion is a critical issue in their applications, and Mg is more prone to be corroded compared to other lightweight metals.

Reviewer 3:

The reviewer said to the extent that the project helps in conveying the various capabilities available in the DOE national laboratories to industry, it supports that objective. The reviewer was not sure how it supports some of the grander DOE vision.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that the team has sufficient facilities, expertise, and human resources to achieve the stated milestones.

Reviewer 2:

The reviewer said that the test cell looks nice, and Magna is more than capable of the various joints of interest.

Reviewer 3:

The reviewer thought that industry should bear 100% of the costs of this project, with perhaps PNNL offering some subject matter expertise in-kind.

Presentation Number: mat144
Presentation Title: Reducing Mass of Steel Auto Bodies Using Thin Advanced High-Strength Steel with Carbon Fiber Reinforced Epoxy Coating
Principal Investigator: Dave Warren, Oak Ridge National Laboratory

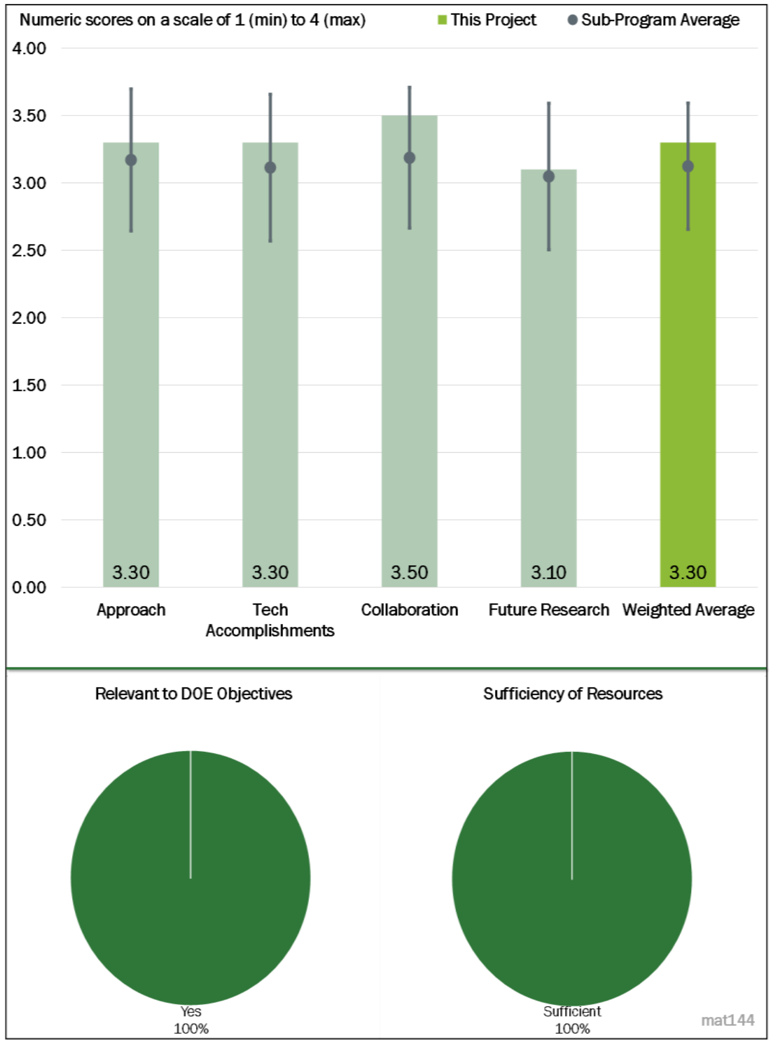

Figure 6-30 - Presentation Number: mat144 Presentation Title: Reducing Mass of Steel Auto Bodies Using Thin Advanced High-Strength Steel with Carbon Fiber Reinforced Epoxy Coating Principal Investigator: Dave Warren, Oak Ridge National Laboratory

Presenter

Dave Warren, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer determined that the project is well-designed and more focused on commercial implementation at coupon and component levels. The reviewer remarked that commercial applicability is very high.

Reviewer 2:

The reviewer said that the approach has a good balance between experimental and simulation. The reviewer would like to see in the future some work on how this would be deployed in production (does it impact upstream/downstream processes) and its cost impact.

Reviewer 3:

The reviewer observed a straight-forward concept that was well-explained and thoughtfully presented. The approach including schedule and milestones are clear and identify tasks. The only comment/question this reviewer has is related to the potential difference in thermal expansion for the two heterogeneous materials that will make up the laminated material system. The question remains: will the project team address the difference in CTE between the steel and C/epoxy substrates. The reviewer said that the build thickness is high enough behind the steel that one would imagine the “bi-material strip” will result in visible deformation through a range of temperatures expected in automotive structure. Thin-gauge steel will undoubtedly exhibit out of plane displacement effecting either appearance or performance (or both). The reviewer said that the approach does not describe requirements or acceptable limits nor any potential issues related to low-cycle fatigue with repeated thermal cycles and the impact on the bond between the steel substrate and CFE. The reviewer recommended that because the economics of this approach to lightweighting are critical to its viability, a simple economic justification for the 15% weight savings should be baked into the project approach to validate cost per kg (lb) of weight saved.

Reviewer 4:
The reviewer said that cost and cosmetic issues are yet to be addressed.

Reviewer 5:
The reviewer commented that the Approach is well-conceived to address the critical aspects of this project. The reviewer would like to also see noise transmission testing in addition to the dent/ding and oil canning evaluations. Including coefficient of linear thermal expansion and corrosion testing ware solid parts of the plan. The reviewer noted that the ELG recycled fiber plus epoxy should increase stiffness. The reviewer asked about the "read through" on the outer panels. The reviewer recommended that given the cost of steel and the cost of epoxy, please address the cost as soon as possible.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer commented that the team is ahead of schedule.

Reviewer 2:
The reviewer remarked that the accomplishments are good for this newly started project. Deciding on the material and process system at this point is a key accomplishment to moving forward with the project.

Reviewer 3:
The reviewer noted that the project started recently.

Reviewer 4:
The reviewer found that technical progress is excellent for a program that only just kicked-off. The project team has been busy and has conducted significant work. The only comment worth considering would be the role of voids in the performance of the system. The reviewer noted how the presenter/PI calls the CFE a "high modulus coating on steel substrates," according to this reviewer nothing could truly be further from fact. The reported material modulus of 4.5 to 5.0 gigapascal is very low. However, the 0.9 specific gravity is also very low such that relatively high thickness can be added without addition of significant mass. The reviewer said that if this approach is technically and economically feasible, it is because of geometry, not material performance. The reviewer said that void content (air) and resulting build thickness is an important contributor (by the power of 3) to bending stiffness of the section. This may be an important property of the material system, i.e., voids and the resulting impact on cost, bending stiffness, and potential performance challenges such as moisture pick-up and fatigue.

Reviewer 5:
The reviewer noted that results presented indicate concerns with the bubbles appearing in the coating. The reviewer thought that it is good the team realizes this an issue and hopefully the team will overcome this in future to align themselves with the performance indicators.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer observed good partners.

Reviewer 2:
The reviewer said excellent collaborative partners, and that work is aptly planned between the cross-cutting members.

Reviewer 3:
The reviewer noted a broad collection of industry, including material suppliers and OEMs.

Reviewer 4:
The reviewer noted a well-constructed make-up of the research team. The rationale and contribution of each team member is described and entirely consistent with the research elements and objectives. The reviewer noted that the presentation does not provide insight into the rhythm of meetings, teleconferences, or other design reviews and face-to-face interaction.

Reviewer 5:
The reviewer said that accomplishments to date indicate a great collaborative effort. The reviewer would like to see a matrix of when and who meets by web-based meetings and face-to-face meetings to better understand the collaborations.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer said that many challenges are to be addressed.

Reviewer 2:
The reviewer remarked that an outline of future work/research is well-described and consistent with the technical requirements of the material system. This reviewer remains concerned about surface distortion as a result of CTE mismatch between metal substrate and CFE. This should likely be evaluated early in the project work so that appropriate actions can be taken to ameliorate any observed effects due to this mismatch and out-of-plane distortion. The reviewer also made a strong recommendation to perform fundamental material cost optimization early in the project to demonstrate/evaluate/report on the incremental cost of materials per unit of mass saved. The reviewer commented that this is very straight-forward and should be used to justify the effort.

Reviewer 3:
The reviewer said that the test plan is clear, but the work would be strengthened with details on how the technology would be deployed in a high-volume automotive environment. Additionally, according to the reviewer the impact of racking on the parts and the potential for delamination will need to be addressed in this project as well (the reviewer noted that the presenter indicated this in fact will be done).

Reviewer 4:
The reviewer said that the proposed future research is good. The reviewer suggested including the NVH characteristics for the outer panel: sound transmission loss, natural frequencies, and torsional stiffness. The reviewer also expressed concern that the epoxy might "peel off" during wind flutter. Please consider checking high cycle fatigue under small amplitude flexing of the panel.

Reviewer 5:
The reviewer said that the team should address the density issue in calculation of mass. According to the reviewer, epoxy and glass/CF density is definitely much higher than what was presented.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer commented that this is a novel and relative simple approach toward significant lightweighting of current vehicle structure; a clearly relevant topic and supports DOE goals and objectives. The reviewer stressed that using an easily applied recycled CF material system to achieve this end is also attractive, and

noted that this provides a positive life-cycle benefit for CF and an overall win for reducing embodied energy, another important DOE objective.

Reviewer 2:
The reviewer observed a novel approach to enable downgauging (lightweighting) of sheet. While the research is focused on UHSS, the same principals could be employed on Al or Mg sheet as well. The reviewer noted that the resin and fiber system would need to be changed, but the overall concept could be applied.

Reviewer 3:
The reviewer said that the project is very relevant to the DOE objectives.

Reviewer 4:
The reviewer said that reducing the mass of our vehicles directly supports the DOE objectives.

Reviewer 5:
The reviewer noted that mass reduction through a mixed material solution is valuable.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that resources are sufficient.

Reviewer 2:
The reviewer remarked team has adequate resources to conduct the proposed research.

Reviewer 3:
The reviewer pointed out that the team is ahead of schedule and project goals seem to be within the bandwidth of the technology.

Reviewer 4:
The reviewer commented at this time, the resources appear sufficient to complete the project on time.

Reviewer 5:
The reviewer said that the objectives of the project are clear, and fairly limited in scope, but provide good value for the dollars spent. While the economic justification remains a bit cloudy to this reviewer, the low-cost research plan and proposed work to be completed should adequately assess the potential for this novel approach of using a combined metallic/non-metallic material solution to automotive panels that require visually attractive surfaces at reduced mass. The reviewer said that resources planned appear adequate to support this plan.

Presentation Number: mat145
Presentation Title: Joining Core Program Overview
Principal Investigator: Richard Davies (Oak Ridge National Laboratory)

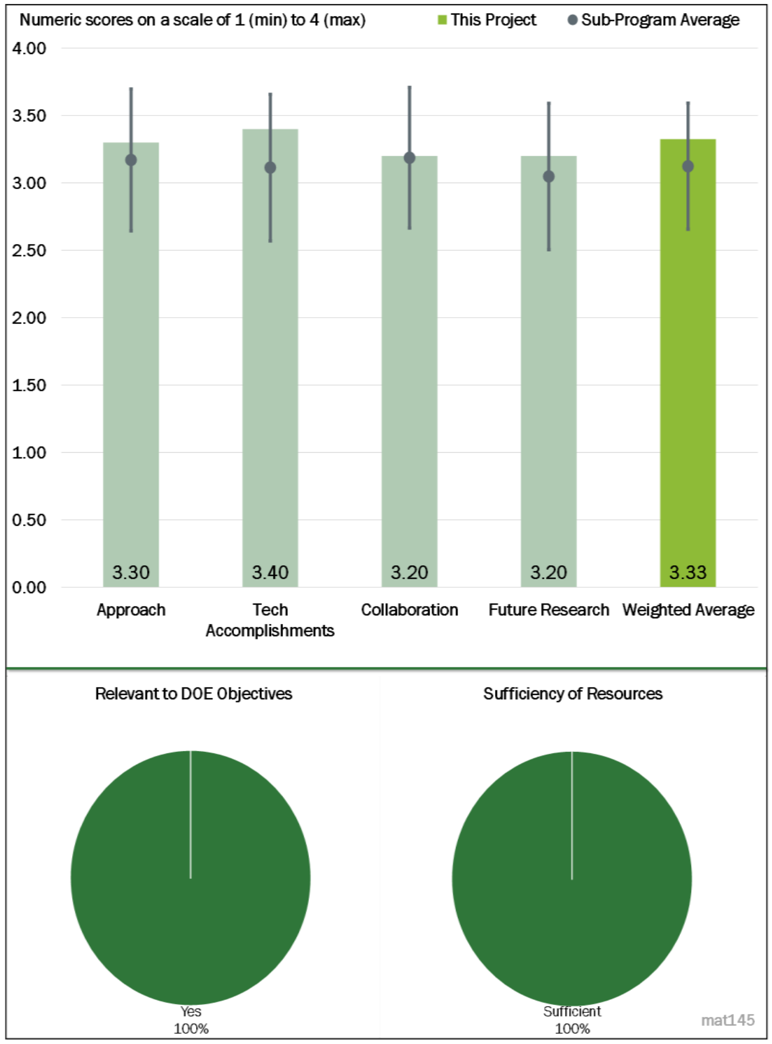

Figure 6-31 - Presentation Number: mat145 Presentation Title: Joining Core Program Overview Principal Investigator: Richard Davies (Oak Ridge National Laboratory)

Presenter

Richard Davies, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that efforts to understand the industry drivers and related technical challenges have been shown to be very beneficial in creating a broad program to address the future of vehicle lightweighting.

Reviewer 2:

The reviewer noted how the core program addresses the important research challenges in dissimilar joining. The reviewer pointed out that Al, which is an important lightweight material, could be addressed more in the future research. The corrosion issue in Mg sheets may hinder their applications in automotive applications.

Reviewer 3:

The reviewer said that the approach presented in the core program sounds very interesting. The reviewer expressed being very interested in reviewing the program status at next year's AMR. The only project that this reviewer questioned its value is joining of Mg alloys to CFCs. The reviewer would like to understand better the rationale for selecting the two lightweight substrates, with the question being the likelihood of the need in joining these two specific substrates together versus other options.

Reviewer 4:

The reviewer said that the approach is based on a work table developed by the Materials Technical Team, which needs to be vetted. The reviewer has have never seen a concept for CFRP/Mg nor CFRP/steel nor Mg/Steel. The reviewer proposed CFRP/Al and Mg/Al as the potential application. An MMLV is an application example that is being ignored.

The reviewer said that Mg sheet will most probably be used in a similar application to CFRP, which includes interior body structures not exposed to stone chipping and road sales and not in primary crash applications. The reviewer said that the Mg sheet alloy identified is only available in Korea from primary Mg produced in China using the Pidgeon process. Further, according to the reviewer, AZ31 Mg sheet is only formable at high temperatures in a quick plastic forming operation that requires several minutes per part to form, not applicable to high volume applications. ZEK100 Mg alloy is manufactured from electrolytic ingot in the United States (US Mag) and rolled by Luxfer Group in Missouri. The reviewer said that Mg ingot has a capacity of 100,000 tons/year in coil form, and it is not subject to the $1 per pound tariff. The reviewer pointed out that ZEK100 Mg is $4/lb, and AZ31 around $12/lb. At the time this Materials Technical Team provided input, the availability of Mg sheet from a U.S. supplier (Luxfer) from U.S. ingot (US Mag) was not commonly known.

Reviewer 5:

The reviewer asked to please look at comments for MAT 136, MAT137, MAT138, and MAT139, because this is the overview introductory brief for all of them. The reviewer had one overarching comment, specifically, why was Al chosen over Mg in these projects.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer was particularly impressed by how this program overview distilled the key industrial challenges into a number of technology projects.

Reviewer 2:

The reviewer commented that the proposed tasks are on track or finished in advance.

Reviewer 3:

The reviewer commented that it appears the basic framework for the technical accomplishments have a solid foundation to work from.

Reviewer 4:

The reviewer observed excellent progress establishing the focus groups, and the authors just need to redefine the material choices. The reviewer cautioned that following the current material set may not result in a positive outcome.

Reviewer 5:

The reviewer said to please look at comments for MAT 136, MAT137, MAT138, and MAT139, because this is the overview introductory brief for all of them.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that efforts have clearly been made to make these drivers the key foci of technology programs. The reviewer noted that integration of DOE only as well as DOE/industry collaboration on these themes is also an effective approach.

Reviewer 2:

The reviewer pointed out that the collaborations are across three national laboratories with industrial suppliers. The unique interface-by-design will facilitate explaining experimental observations and help to design the joining process in a faster manner. The reviewer added that will be nice to demonstrate the results with an OEM.

Reviewer 3:

The reviewer said that from a collaboration point of view, no references to specific adhesive suppliers were made, and the reviewer is not sure whether such references were left out and it was expected to be covered by other subprojects where adhesives were being considered to be used. The reviewer said that the same holds true for composites, the only reference was to BASF supplying thermoplastic plaques. The reviewer asked if this means thermoset composites are outside of the scope.

Reviewer 4:

The reviewer noted how the project team is limited to ORNL and PNNL. The reviewer recommended that there should be an advisory board comprised of industry.

Reviewer 5:

The reviewer said to please look at comments for MAT 136, MAT137, MAT138, and MAT139, because this is the overview introductory brief for all of them. The reviewer recommended that in projects where only ORNL and PNNL are partnered, an industry/transition partner is also included.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer pointed out that future work is discussed in each individual project.

Reviewer 2:

The reviewer liked the planning at this level, but was not as impressed with the organization of the projects that make up the overall portfolio here.

Reviewer 3:

The reviewer noted that many of the projects are new and this is the first year they are being reviewed. However, they all have an overarching framework for future work based on the level of completion of the project.

Reviewer 4:

The reviewer said that the future plan is excellent with the exception of the material set.

Reviewer 5:

The reviewer said please look at comments for MAT 136, MAT137, MAT138, and MAT139, because this is the overview introductory brief for all of them.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer commented that the approach presented to cover the key topics at a fundamental scientific level is excellent and it was a much-needed initiative.

Reviewer 2:

The reviewer said that the program is a clear element of the DOE strategy on improving vehicle energy efficiency.

Reviewer 3:

The reviewer commented that multi-material joining is the cornerstone of the future of lightweighting.

Reviewer 4:
The reviewer remarked that dissimilar material joints can save the weight of structure, improve fuel efficiency, and reduce air pollution. The research scope supports the overall DOE objectives very well.

Reviewer 5:
The reviewer said to please look at comments for MAT 136, MAT137, MAT138, and MAT139, because this is the overview introductory brief for all of them. The reviewer added that multi-material joining is a huge part of DOE's and the automotive industry's vision for lightweighting.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer said that there appears to be efficient utilization of resources.

Reviewer 2:
As stated previously, this reviewer was impressed with the degree of industry/DOE national laboratory coordination on this effort.

Reviewer 3:
The reviewer noted that the team has sufficient facilities, expertise, and human resources to achieve the stated milestones across three national laboratories.

Reviewer 4:
The reviewer asserted that sufficient resources are deployed.

Reviewer 5:
The reviewer asked to please look at comments for MAT 136, MAT137, MAT138, and MAT139, because this is the overview introductory brief for all of them.

Acronyms and Abbreviations

°C	Degree Celsius
3GAHSS	Third-Generation Advanced High-Strength Steel
3-D	Three-dimensional
AI	Artificial intelligence
Al	Aluminum
AMR	Annual Merit Review
AZ31	Magnesium alloy
C	Carbon
CAE	Computer-Added Engineering
CF	Carbon fiber
CFC	Carbon fiber composites
CFRP	Carbon fiber-reinforced polymer
CGI	Compacted graphite iron
CPEC	Close Proximity Electromagnetic Carbonization
CRADA	Cooperative research and development agreement
CTE	Coefficient of thermal expansion
Cu	Copper
DOE	U.S. Department of Energy
E	Young's modulus
EM	Electromagnetic
EMN	Energy Materials Network
FBJ	Friction Bit Joining
FLD	Forming Limit Diagram
FSW	Friction Stir Weld
FY	Fiscal Year
GHG	Greenhouse Gas
GM	General Motors

HCP	Hexagonal closed pack
HPC	High-performance computing
HP-RTM	High-Pressure Resin Transfer Molding
ICME	Integrated Computational Materials Engineering
kWh	Kilowatt hour
L	Liter
lb	Pound
LightMAT	Lightweight Materials Consortium
LTC	Low-temperature carbonization
Mg	Magnesium
MgO	Magnesium oxide
MMC	Metal-matrix composites
MMLV	Multi Material Lightweight Vehicle
Mn	Manganese
NCF	Non-crimp fabrics
Ni	Nickel
NVH	Noise, vibration, and harshness
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PDF	Pair distribution function
PI	Principal investigator
PNNL	Pacific Northwest National Laboratory
Pt	Platinum
R&D	Research and Development
RTM	Resin transfer molding
RVE	Representative volume element
SMC	Sheet molding compound
Ti	Titanium

TiAl	Titanium aluminides
TiB_2	Titanium diboride
TRL	Technology readiness level
UHSS	Ultra-High Strength Steels
USAMP	United States Automotive Materials Partnership
V	Vanadium
VTO	Vehicle Technologies Office
YS	Yield strength
ZEK100	Magnesium alloy

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7. Technology Integration

To strengthen national security, enable future economic growth, support energy dominance, and increase transportation energy affordability for Americans, the Vehicle Technologies Office (VTO) funds early-stage, high-risk research. The research will generate knowledge that industry can advance to deploy innovative energy technologies to support affordable, secure, reliable and efficient transportation systems across America. VTO leverages the unique capabilities and world-class expertise of the national laboratory system and works with partners across industry and academia to develop new innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures and better powertrains; and energy efficient mobility technologies and systems, including connected and automated vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement. VTO is uniquely positioned to address early-stage challenges due to its strategic research partnerships with industry (e.g., the U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise. These partnerships prevent duplication of effort, focus U.S. Department of Energy (DOE) research on the most critical research and development (R&D) barriers, and accelerate progress. VTO focuses on research that industry either does not have the technical capability to undertake on its own—usually because there is a high degree of scientific or technical uncertainty—or it is too far from market realization to merit sufficient industry emphasis and resources.

The Technology Integration (TI) subprogram covers a broad technology portfolio that includes alternative fuels (e.g., biofuels, electricity, hydrogen, natural gas, propane) and energy efficient mobility systems. These technologies can strengthen national security through fuel diversity and the use of domestic fuel sources, reduce transportation energy costs for businesses and consumers, and enable energy resiliency with affordable alternatives to conventional fuels that may face unusually high demand in emergency situations. The subprogram supports Data and Systems Research activities, including "living lab" projects—i.e., competitively-awarded projects to validate data, technologies, and systems in the field, serving as an important feedback loop to inform future Vehicle Technologies research planning. TI also supports Vehicle Technologies statutory requirements related to alternative fuels and the annual Fuel Economy Guide, and includes the Advanced Vehicle Competitions activity that supports science, technology, engineering, and mathematics (STEM) and workforce development interests.

Subprogram Feedback

DOE received feedback on the overall technical subprogram areas presented during the 2018 Annual Merit Review. Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. The subprogram overview questions are listed below, and it should be noted that no scoring metrics were applied.

Question 1: Was the program area, including overall strategy, adequately covered?

Question 2: Is there an appropriate balance between near- mid- and long-term activities?

Question 3: Were important issues and challenges identified?

Question 4: Are plans identified for addressing issues and challenges?

Question 5: Was progress clearly benchmarked against the previous year (for multi-year projects)?

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Question 10: Has the program area engaged appropriate partners?

Question 11: Is the program area collaborating with them effectively?

Question 12: Are there any gaps in the portfolio for this technology area?

Question 13: Are there topics that are not being adequately addressed?

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: ti918
Presentation Title: TI Overview
Principal Investigator: Mark Smith (U.S. Department of Energy)

Question 1: Was the program area, including overall strategy, adequately covered?

Reviewer 1:
This reviewer responded positively and felt that the presenter did a great job of going over high-level TI objectives, while still detailing some of the highlighted projects.

Reviewer 2:
The reviewer commented that the presentation did a very good job of laying out overall program elements of the TI Team as well as relevance and importance of core activities to the VTO and DOE.

Reviewer 3:
The reviewer stated yes; the presentation adequately covers the TI program strategy.

Question 2: Is there an appropriate balance between near- mid- and long-term activities?

Reviewer 1:
This reviewer stated yes; the presenter showed the group’s near- and long-term goals, of which there was a good balance.

Reviewer 2:
Although the presentation did not explicitly identify near-, mid-, and long-term activities, this reviewer noted that it did cover the full timeframe. Many of the activities were near-term, including first responder training, technical assistance, information and tools, and aggregate purchasing power. The reviewer reported that mid-term activities included the high visibility demonstration, best practices, permitting and safety issues, and Technologists-in-City pilots. Long-term activities highlighted by this reviewer included informing living labs and workforce development, and curriculum development.

Reviewer 3:
This reviewer indicated that there is too much emphasis on historic and current activities and not enough information about future activities, especially mid- and long-term activities.

Question 3: Were important issues and challenges identified?

Reviewer 1:
The reviewer stated yes; the presentation adequately identifies important issues and challenges.

Reviewer 2:
Important issues and challenges observed by this reviewer included workforce development; technical assistance, gap analysis, and feedback; policy deployment; and aggregating purchasing power.

Reviewer 3:
This reviewer commented that the presenter did a good job of highlighting some of the issues that TI attempts to tackle. However, the reviewer did not see a lot of detail regarding issues and challenges because this was an overview presentation.

Question 4: Are plans identified for addressing issues and challenges?

Reviewer 1:
The reviewer asserted that plans and activities addressed all key challenges and issues.

Reviewer 2:
This reviewer explained that the presenter did a good job of identifying some of the overarching challenges that TI is attempting to tackle and showed examples of funded projects to address these.

Reviewer 3:
The reviewer stated no; the presentation focused solely on historic and current activities. The reviewer observed no information in the presentation about plans for addressing issues and challenges.

Question 5: Was progress clearly benchmarked against the previous year (for multi-year projects)?

Reviewer 1:
The reviewer indicated that, as a program overview, it did not specifically address progress against the previous year. Project examples were provided, but the progress aspect was left to the more detailed, project reviews that followed. The reviewer described this approach as appropriate.

Reviewer 2:
The reviewer explained that this question did not apply because the presentation was an overview. The presenter did show enacted budgets for this year and last year.

Reviewer 3:
This reviewer stated no; the presentation included no information benchmarking progress against the previous year.

Question 6: Are the projects in this technology area addressing the broad problems and barriers that the Vehicle Technologies Office (VTO) is trying to solve?

Reviewer 1:
The reviewer indicated yes; TI is an important solution component to the question that VTO is attempting to address.

Reviewer 2:
This reviewer responded positively and noted that current projects are addressing the broad problems and barriers that VTO is trying to solve. The reviewer suggested that the presentation would be improved with a discussion of plans for continuing to do so in the mid- and long-term.

Reviewer 3:
Although the projects address workforce development and best practice sharing, the reviewer thought that the demonstration project needs more metrics to demonstrate success.

Question 7: Does the program area appear to be focused, well-managed, and effective in addressing VTO's needs?

Reviewer 1:
This reviewer responded positively and noted that the program area appears to be focused, well-managed, and effective in addressing VTO's needs.

Reviewer 2:
The reviewer stated yes; the program area is well-focused and managed, based on the presentation.

Reviewer 3:
This reviewer observed well-defined tool development and information that appear to be hitting the target audience. The reviewer explained that the demo projects seem to lose steam and need a better process for developing and transferring lessons learned.

Question 8: What are the key strengths and weaknesses of the projects in this program area? Do any of the projects stand out on either end of the spectrum?

Reviewer 1:

The reviewer commented that first responder training and deployment is a real strength, and that the EcoCAR program is outstanding, well-managed, and continues to improve and expand. Regarding the Clean Cities coalition network, the reviewer pointed out that it plays a key role in linking stakeholders as well as deploying awareness and best practices.

Reviewer 2:

This reviewer described the Clean Cities Coalitions as a strength of TI. Further, the reviewer noted that projects funded through TI go a long way in helping VTO meet its long- and near-term goals.

Reviewer 3:

The reviewer explained that key strengths include ongoing efforts to collaborate with fleets through Clean Cities projects, coordinators, and funding; and to educating fleets and the public through the Alternative Fuels Data Center (AFDC) and fueleconomy.gov websites. The key weakness identified by this reviewer is a lack of vision for mid- and long-term planning. Acknowledging that the projects in this program area have been successful for years, the reviewer inquired about what the future holds and whether the program area can adjust with future issues and/or needs.

Question 9: Do these projects represent novel and/or innovative ways to approach these barriers as appropriate?

Reviewer 1:

This reviewer responded positively and felt that the TI-funded projects represent innovative ways of removing technical barriers to meeting VTO's overarching goals.

Reviewer 2:

The reviewer stated yes; the projects represent novel and/or innovative ways to approach the barriers identified, and the projects have been recognized as leaders in their fields for years. The question considered by this reviewer is whether that can continue.

Reviewer 3:

Although the projects in this portfolio are very important, this reviewer did not think they are particularly novel. The reviewer advised that thoughtful consideration of key outputs and metrics could be helpful.

Question 10: Has the program area engaged appropriate partners?

Reviewer 1:

The reviewer indicated yes and described partner engagement as one of the program area's strengths, especially in its partnerships with fleets, Clean Cities Coalitions, and national laboratories.

Reviewer 2:

This reviewer responded positively and observed a broad set of partners including Clean Cities, universities, national laboratories, and industry.

Reviewer 3:

The reviewer answered yes and commented that the program has a good spread of industry, government, academia, and national laboratory partners.

Question 11: Is the program area collaborating with them effectively?

Reviewer 1:
Based on the presentation, this reviewer felt that the program collaborates effectively with its partners.

Reviewer 2:
The reviewer stated yes; the program area collaborates with its partners effectively and has done so for many years. The reviewer hoped that this can continue.

Reviewer 3:
This reviewer responded positively and noted that the program area appears to be collaborating with individual and regional stakeholders. The reviewer was unsure whether the program area gets the most out of best practice sharing.

Question 12: Are there any gaps in the portfolio for this technology area?

Reviewer 1:
This reviewer observed no gaps in the portfolio for this technology area and asserted that the portfolio is appropriate for the program area's objectives.

Reviewer 2:
There were no obvious gaps noted by this reviewer, though a stronger relationship between gap analysis and technology roadmaps was recommended.

Reviewer 3:
Although the presentation lacked great detail on specific projects funded by TI, this reviewer did not see any gaps in the portfolio from a high level.

Question 13: Are there topics that are not being adequately addressed?

Reviewer 1:
This reviewer observed no inadequately addressed topics, but advised that the program needs to continue engaging with fleets and consumers to stay on top of issues as they evolve.

Reviewer 2:
The reviewer did not notice any topics that were not being adequately addressed even though the presentation lacked any great detail of the TI-funded programs.

Reviewer 3:
This reviewer identified policy deployment and collaboration between major industry players.

Question 14: Are there other areas that this program area should consider funding to meet overall programmatic goals?

Reviewer 1:
Based on the presentation, the reviewer did not see any other areas that the program should consider funding to meet its overall programmatic goals.

Reviewer 2:
This reviewer stated no; the program area just needs to stay engaged as technologies and personal mobility choices evolve.

Reviewer 3:

The reviewer suggested that TI should consider pulling together a high-level summary roadmap that covers all of VTO, as well as engaging the light-, heavy-, personal, and commercial sectors in periodic crosstalk similar to what is done in the combustion area.

Question 15: Can you recommend new ways to approach the barriers addressed by this program area?

Reviewer 1:

This reviewer did not have any specific recommendations for ways to approach the barriers addressed in this program area.

Reviewer 2:

The reviewer recommended facilitating more cross-sector and cross-industry discussions.

Reviewer 3:

This reviewer suggested more emphasis on engaging a younger consumer audience; there are likely to be significant changes in personal mobility choices over the next 20-30 years, with new technologies and new ways of viewing transportation options. The program must stay engaged with this younger audience to remain relevant. The reviewer forecasted that the old "one car per person" model is likely to disappear and cautioned that the program cannot get caught up in doing "business as usual."

Question 16: Are there any other suggestions to improve the effectiveness of this program area?

Reviewer 1:

This reviewer did not have any suggestions to improve the effectiveness of this program area.

Reviewer 2:

The reviewer stated no and suggested that the program area continue engaging fleets and consumers and adapting to their needs.

Reviewer 3:

This reviewer advised to stay focused and relevant.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 7-1—Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page #	Objectives	Approach	Accomplishments	Collaboration	Overall Impact	Weighted Avg.
ti070	Advanced Vehicle Technology Competitions—EcoCAR	Kristen Wahl (ANL)	7-10	3.75	3.81	3.94	3.69	3.75	**3.83**
ti079	Training for Cost-Effective, Code-Compliant Gaseous Fuel Maintenance Facilities	Ted Barnes (Gas Technology Institute)	7-18	3.50	3.50	3.30	3.50	3.00	**3.37**
ti080	Safety Training and Design, Permitting, and Operational Guidance for Gaseous Fuel Vehicle Facilities	Rob Adams (Marathon Technical Services USA)	7-23	3.50	3.60	3.60	3.60	3.30	**3.55**
ti081	WestSmartEV: Western Smart Plug-In Electric Vehicle Community Partnership for Electric Vehicles and Infrastructure	Chad Teply (PacificCorp)	7-28	3.50	3.50	3.50	3.50	3.33	**3.48**
ti082	U.S. Fuels Across America's Highways—Michigan to Montana (M2M)	Ted Barnes (Gas Technology Institute)	7-31	3.50	3.50	3.00	3.50	3.17	**3.27**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page #	Objectives	Approach	Accomplishments	Collaboration	Overall Impact	Weighted Avg.
ti083	Midwest EVOLVE (Electric Vehicle Opportunities: Learning, Events, Experience)	Lisa Thurstin (ALA of Upper Midwest)	7-34	3.50	3.50	3.38	3.50	3.38	**3.44**
ti084	Northwest Electric Vehicle Consumer Showcase	Jeff Allen (Drive Oregon [Forth])	7-38	3.63	3.50	3.25	3.38	2.88	**3.35**
ti085	Advancing Plug-In Electric Vehicle Adoption in New England through Events and Outreach	Joel Levin (Plug-In America)	7-42	3.33	3.33	3.33	3.33	3.17	**3.32**
Overall Average				**3.56**	**3.57**	**3.49**	**3.53**	**3.30**	**3.50**

Presentation Number: ti070
Presentation Title: Advanced Vehicle Technology Competitions—EcoCAR
Principal Investigator: Kristen Wahl (Argonne National Laboratory)

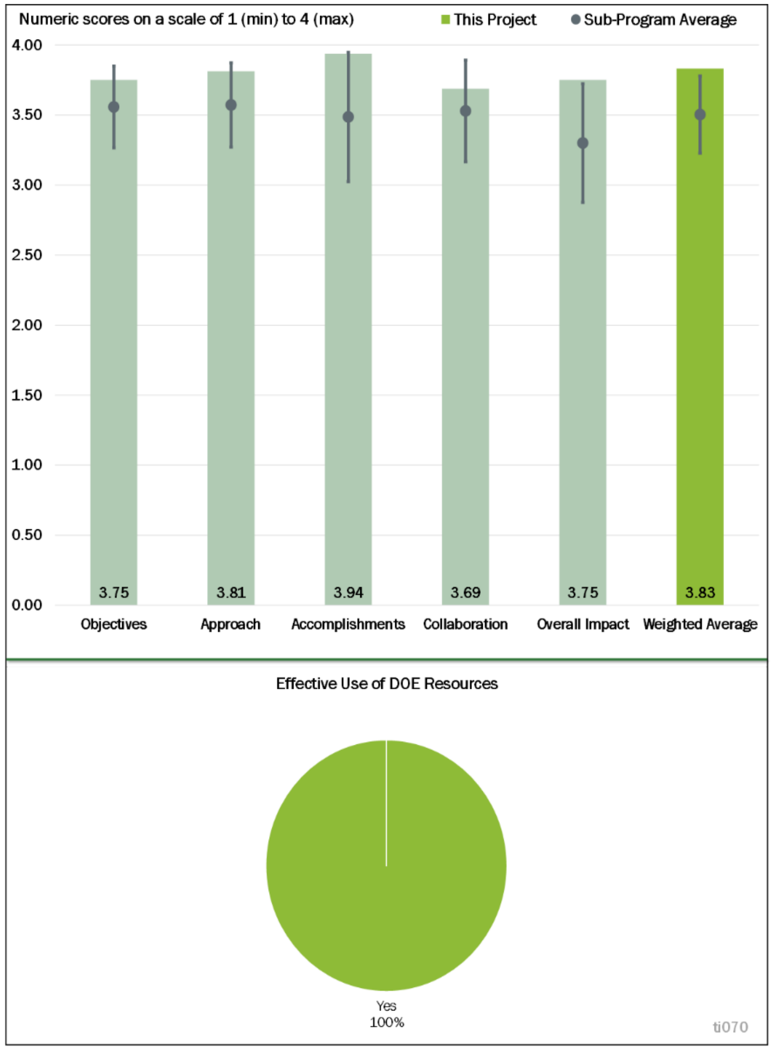

Figure 7-1 - Presentation Number: ti070 Presentation Title: Advanced Vehicle Technology Competitions—EcoCAR Principal Investigator: Kristen Wahl (Argonne National Laboratory)

Presenter

Kristen Wahl, Argonne National Laboratory

Reviewer Sample Size

A total of eight reviewers evaluated this project.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer noted this is a terrific program that draws attention and interest to DOE's VTO program objectives and helps to train engineers and professionals who can be employed in activities that promote alternative fuel use and efficient vehicles.

Reviewer 2:

The reviewer noted that this project has a proven record of developing and showcasing talented students to seed the automobile industry with experienced, enthusiastic, and dedicated advanced technology engineers. The idea behind hosting a technology competition is solid, and the reviewer described the program as well-conceived and fully supported by original equipment manufacturers (OEM) manufacturers and suppliers. The reviewer could think of no better way to support the goal of developing future technicians and engineers.

Reviewer 3:

This reviewer explained that project objectives have been achieved through tremendous real-world experiences for the future innovators and engineers with a contagious enthusiasm and impressive results. It was easy for this reviewer to understand why students are motivated to participate, how much they are able to learn, and how it equips them for a successful career in automotive engineering.

Reviewer 4:

The reviewer commented that the program focuses on creating real world hands-on experience for university engineering students to develop new integrated technical solutions for new vehicles. The focus on new fuels and new technologies is consistent with DOE's objective of increasing fuel diversity.

Reviewer 5:

The reviewer highlighted the following: the project clearly addresses a lack of trained engineers and scientists, which is cited as a barrier; advanced vehicle technology curricula emphasizes experimental learning; Argonne National Laboratory (ANL) performed a fair competition for EcoCAR year 3 as targeted; and the powertrains demonstrated clearly met safety and efficiency goals.

Reviewer 6:

The reviewer noted that the project supports the DOE/VTO objectives of increasing fuel diversity through alternative fuel use and increasing transportation efficiency. The project objectives accomplish this primarily by "seeding" the automotive industry with future innovators and engineers with real-world experience in advanced vehicle technologies; demonstrating advanced vehicle technologies and alternative fuels that can increase transportation energy efficiency; and ensuring that the technical integrity of advanced vehicle technologies aligns with automotive industry standards. Each of these items, as asserted by this reviewer, helps ensure that the automotive industry will continue to develop advanced, energy-efficient vehicle technologies in the future.

Reviewer 7:

The reviewer identified two strengths: the project represents a mature, robust advanced vehicle technology workforce development effort that strongly supports DOE/VTO objectives; and the program includes an advanced driver assistance system (ADAS) component, paving the way for further integration of connected autonomous vehicle technologies into future EcoCAR competitions.

Reviewer 8:

According to the reviewer, the objectives for this project were well-described and address the barriers noted in the overview slide. Additionally, the reviewer suggested proportionally addressing barriers and project objectives on the project objective slides to improve the presentation. Although most of the barriers quadrant focuses on the lack of skilled workforce and workforce development, this reviewer reported that three-fourths of the objectives slide focuses on the demonstration, competition, and showcase element.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer commented that the program appeared to be well-designed and run and did not have suggestions for improvement.

Reviewer 2:

According to the reviewer, EcoCAR continues to build on the success of previous competitions and does an excellent job of encouraging, educating, and fostering young talent for the automotive industry to create future generations of advanced technology vehicles. This reviewer observed a thoroughly researched, well-conceived, and expertly executed program.

Reviewer 3:

The reviewer indicated that the project has very specific and well-conceived goals and deliverables. It is very results-oriented and continues to evolve and grow over the years.

Reviewer 4:

The reviewer remarked that the project approach supports the integration of advanced transportation technologies and practices to support overall project objectives. The project is well-designed, feasible, and aligned with other efforts, and does an excellent job of bringing together automotive industry representatives with university staff and students to replicate real-world experience in developing advanced vehicle technologies. The project is also well-aligned with other VTO efforts, especially Clean Cities University, that are intended to ensure a well-trained engineering workforce that continues advanced technology vehicle development.

Reviewer 5:

The reviewer noted that the approach seems most appropriate considering the real-world, hands-on experience the students receive, their exposure to the multi-year vehicle development process that is modeled after the auto industry, and the competitive environment that enhances the comprehensive engineering education, training, and mentoring the students receive.

Reviewer 6:

The reviewer observed the following strengths: the project's four-year design curriculum that allows for a comprehensive automotive workforce development program (encompassing engineering; electronics/computing; project management; communications; STEM education; etc.); and the program's rigorous and thorough vehicle safety inspections.

Reviewer 7:

This reviewer acknowledged an outstanding approach that prepares the students for a career in the automotive industry: year 1, modeling and simulation; year 2, integration into an existing vehicle; year 3, system full functionality; and year 4, "showroom ready," followed by "take to the road." The reviewer was impressed by the number of Clean Cities internships—114 interns/year. This reviewer also reported that the project approach emphasizes partner collaboration, including significant cost share ($88 million), which allows the teams to tap into needed resources. The reviewer also noted that the briefing was unclear as to which specific advanced technology vehicle categories/types were advanced in the competition.

Reviewer 8:

It was clear to the reviewer that this project used a thoughtful and deliberate approach for achieving its goals that very much parallels the industry development path. The reviewer thought there was an excellent emphasis on safety, integration with university curricula, and leveraging of Clean Cities, including intern placement across North America. For the presentation, it was challenging for the reviewer to follow the milestones slide because the project start was excluded, years 1 and 2 were unmentioned, and there was no project end milestone indicated. The reviewer suggested that the slide could be better framed to best orient the audience to the time period of focus.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:

The reviewer asserted that the project is outstanding in terms of accomplishments and demonstrated progress toward project objectives and DOE goals. The following significant accomplishments were highlighted by this reviewer: vehicle integration, safety, and testing; vehicle development; emissions testing and development; ADAS development; innovation; project management and communications; STEM outreach and community involvement activities; and media and public relations exposure. The reviewer noted that the number and variety of the project's accomplishments demonstrates how well the project aligns with DOE objectives in all facets of developing, testing, deploying, and promoting advanced technology vehicles to increase energy efficiency in transportation.

Reviewer 2:

It was obvious to the reviewer that EcoCAR's success was demonstrated in the number of program alumni who have gained employment with advanced vehicle technology manufacturers and supplier companies. The reviewer also noted that the program attracts the best and brightest students from the best engineering schools, and channels them into the automobile industry.

Reviewer 3:
The reviewer noted that annual participation rates, program competitiveness, and the number of students that have participated attest to the program's value and achievements.

Reviewer 4:
The reviewer reported that the project is a competition with very specific metrics, and that every team accomplishes major deliverables even though there is an overall winner.

Reviewer 5:
According to the reviewer, year 3 of EcoCAR met or exceeded all milestones, and the teams were largely successful meeting vehicle safety inspection (13/16, 14/16). This reviewer also pointed out that vehicle testing yielded several strong performances in acceleration, breaking, lateral acceleration, and energy consumption. Mileage accumulation (100 to 1,000) and continuous endurance drive (50 to 200m) were very impressive to the reviewer, as was total mileage accumulation (13,764) and teams that met mileage and endurance goals (9 of 16). This reviewer further highlighted that the expansion into ADAS activity demonstrates the EcoCAR program's evolution as technology continues to evolve.

Reviewer 6:
The reviewer thought that the project accomplishments and progress were impressive for the teams that successfully completed their integration and inspections, but expressed disappointment in seeing that several teams did not successfully complete their projects or participate in all of the workshops. The reviewer also noted that the expanded reach of the STEM outreach and community involvement program was especially gratifying to see.

Reviewer 7:
This reviewer offered feedback with respect to content and delivery. Regarding content, the reviewer noted that teams overachieved the goals set out for them. Specific accomplishments mentioned included the following: 90% of teams were 100% integrated, and 14 of 16 teams passed safety tests, which is higher than average; 11 of 16 teams made it to the finals round, which is the most ever; and 13 of 16 completed dynamic test events. The reviewer suggested that it would be good to highlight why certain teams missed their targets.

Continuing input regarding content, the reviewer found it notable that the teams had the opportunity to access the chassis dynamometer and that all teams passed safety inspection for dynamometer testing. The reviewer was extremely impressed to see the incorporation of ADAS elements into the project and that the project accommodated high-risk investigations outside the critical path in order to attract a greater diversity of talent and spur innovation. The reviewer said incorporating project management and communications topics was also laudable for contributing to the sense that the project provided a comprehensive and rounded learning experience that would have direct workforce applicability.

Regarding delivery, this reviewer would have liked to have seen results presented in tabular or chart form in which the project and team goals were specifically delineated and the accomplishments were compared against these targets. The reviewer also thought it would be helpful to provide a reference point or baseline on which to judge the accomplishments against previous efforts.

Reviewer 8:
None were noted by this reviewer.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:

The reviewer asserted that the results speak for themselves, especially statistics on the high percentage of graduates going to work in the automotive industry. It was also gratifying for this reviewer to see the strong collaboration between government and industry sponsors.

Reviewer 2:

The reviewer observed an outstanding project regarding the degree to which team members and partners are involved in the project work, as well as the level of effective collaboration between and among partners. The real strength of the project is in the outstanding collaboration among all involved parties: DOE, General Motors (GM), 30 other government and industry sponsors, 16 universities, and ANL. The reviewer explained that this unique collaboration helps ensure that future automotive engineers get real-world experience in developing, testing, deploying, and promoting advanced, fuel-efficient vehicle technologies, further promoting the DOE objective of energy-efficient transportation.

Reviewer 3:

The reviewer noted that EcoCAR has a large number of partners, many of them large corporations, yet manages to coordinate effectively between them to foster collaboration and active participation in the program. Many sponsors lend time, talent, and resources to assist the student teams, rather than just providing monetary support.

Reviewer 4:

The reviewer opined that new coordination with the National Science Foundation (NSF) will ensure a "technology push" into the EcoCAR program as basic R&D can be matured in this program with low technology readiness level concepts. The reviewer reported that each team has a communications manager that has helped bolster knowledge of the program and attracted more students and sponsors. Project management training provided to ensure the teams were aware of milestones, budgets, fundraising, and risk management appeared to have paid off smartly by this reviewer. The reviewer also described the 251 million total impressions in year 3 of EcoCAR as very impressive. This reviewer observed very strong STEM outreach for the next generation of participants, and added that having 333 total youth events over 3 years and reaching out to 10,000 students is key to strong continuation.

Reviewer 5:

The reviewer remarked that the program blends the best of both the competitive and the collaborative models. Teams were motivated to compete, and the program not only had an overall winner but had competitive elements throughout the four years of the project. The reviewer thought the project emphasized collaboration and sharing and provided information and best practices throughout the program to even up the teams.

Reviewer 6:

The reviewer noted two project strengths including leveraging participation and subject matter expert (SME) knowledge from other DOE/VTO programs and agencies (e.g., the NSF), and leveraging substantial industry and partner funding. One weakness noted by the reviewer was that effort does not yet involve other OEMs or the United States Council for Automotive Research.

Reviewer 7:

The reviewer commented that the project clearly demonstrated incorporation of an extraordinarily high degree of collaboration across industry, government, and academic sectors. The project clearly left the impression that it explored every opportunity to leverage the investment of government and sponsor funds to achieve significant impact. For example, this reviewer highlighted its partnership with NSF to deliver STEM-focused education to teach students about marketing, outreach, and communications. The reviewer also suggested spending more time discussing the various forms of collaboration that resulted, especially noting any new collaborations that might have emerged as a result.

Reviewer 8:

Based on the presentation, the reviewer noted that there appeared to be a strong team in place to support the individual universities, but was unsure how much collaboration exists between different partners.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer commented that the excitement, interest, and young professionals facilitated by this program will go a long way toward advancing alternative fuel and efficient vehicle use.

Reviewer 2:

The reviewer remarked that the fact that so many graduates go to work in the automotive industry and that such a high percentage of Advanced Vehicle Technology Competitions (AVTC) alumni are responsible for protected intellectual property spoke highly of the program's success and the excellent technical training and mentoring received by graduates.

Reviewer 3:

The reviewer thought that the project's overall impact since 2014 has been excellent. In the reviewer's view, the project has already contributed, and will continue to contribute in the future, to increasing fuel diversity through using alternative fuels and increasing transportation efficiency. The project has "seeded" the automotive industry with hundreds of engineers with real-world experience in developing, testing, deploying, and promoting fuel-efficient, advanced technology vehicles. The reviewer said that 85% of project graduates go to work in the automotive industry, where they make significant contributions to advanced technology vehicles. Further, the project delivers a "diverse fleet of student-built prototype vehicles" that provide valuable data for research and education. Lastly, the project fosters strong collaboration among all participants, contributing to future efforts to educate automotive engineers and to develop fuel-efficient transportation technologies.

Reviewer 4:

The reviewer described EcoCAR as a fine example of a tailored, government-led program in partnership with academia and industry that continuously achieves great impact. With strong support from academia, the students' education is more industry-relevant while simultaneously accomplishing other important objectives such as team-building, fundraising, STEM outreach, and problem solving. The reviewer also noted that data such as 85% of EcoCAR participants going to work in the automotive industry and 53% being part of intellectual property within 2 years of working in industry is a testament to the program's impact on making students "job-ready."

Reviewer 5:

Based on past performance, the reviewer believed that EcoCAR and its successors will continue to have a significant impact by attracting and developing quality engineering talent to pursue careers in advanced technology vehicles.

Reviewer 6:

The reviewer indicated that the most important impact of this program is creating future engineers and researchers. As stated, 25,000 engineers have come through the program since its inception, and these engineers are the industry's future.

Reviewer 7:

The reviewer noted the following strengths: schools get to keep the cars for ongoing education; historically, 85% of graduates have entered the automotive industry workforce; and technical work conducted by school teams provides important data back to R&D staff at GM. As a minor weakness, the reviewer suggested that the program further increase engagement of high school and community college automotive/vocational programs.

Reviewer 8:

The reviewer thought the project clearly demonstrated significant impact with key metrics such as delivering 25,000 graduates since 1988 with an impressive 85% choosing employment in the automobile industry. The reviewer suggested providing a reference baseline on presentation slides against which to judge the metrics. For example, this reviewer asked how the cited 53% of GM-hired AVTC alumni with at least one piece of protected intellectual property compare against the baseline of all new hires or specific groups of new hires. Additional metrics of note for the overall impact slide were the number of academic papers produced, media impressions, patents filed for or issued, etc. Some were sprinkled throughout the accomplishments/progress section or otherwise raised during the question and answer period. The reviewer noted it would have been easier to follow and would have left a greater impression on the audience if the accomplishments/progress section focused on progress against the project plan and addressed accomplishments, achievements, and impacts in the final section.

This reviewer indicated that some of the notable achievements that could have been added in the impacts part of the presentation include the following: 50% of GMs hires have at least one piece of intellectual property within 2 years of working with the company; students know how to hit the ground running; and graduates earn about 10%-15% more than their peers in industry out of college. In sum, the reviewer would have liked more specific evidence of the project's impact presented in the slides such as details on types of patents awarded, changes to university curricula to create more advanced vehicle technology curricula, and cross-pollination such as interdisciplinary programs.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The reviewer stated that DOE funding was strongly leveraged through this well-developed project.

Reviewer 2:

The reviewer opined that the program represented a modest investment of DOE's resources and was well worth it.

Reviewer 3:

The reviewer described the use of resources as appropriate and consistent with the size of this project, and that additional resources from cost-sharing participants helped the program accomplish even larger objectives than would have otherwise been achievable. The reviewer also pointed out that GM deserves special recognition for the use of vehicles, the Milford track, and other contributions to this exceptional program.

Reviewer 4:

The reviewer asserted that the program was well worth the investment and, based on the number of qualified engineers and scientists the program has produced, efforts should be made to expand it to additional schools.

Reviewer 5:

The reviewer remarked that DOE resources were being leveraged and funds were being used wisely. The project features strong collaboration with more than 30 government and industry sponsors who contribute funding and in-kind support. The reviewer explained that the return on DOE investment was worthwhile given the project's success in helping develop an automotive engineering workforce with real-world experience in all facets of advanced vehicle technology development and deployment.

Reviewer 6:

There are few projects of which this reviewer was aware that can justifiably claim to leverage government funds to magnify project impact. It was difficult for the reviewer to see how the project team could have performed better in this regard.

Reviewer 7:

The reviewer believed EcoCAR is an excellent use of DOE funds and has proven its value by leveraging millions of dollars in capital and resources from partner sponsors.

Reviewer 8:

The reviewer observed a highly-leveraged program in which many industry stakeholders contribute resources and funding.

Presentation Number: ti079
Presentation Title: Training for Cost-Effective, Code-Compliant Gaseous Fuel Maintenance Facilities
Principal Investigator: Ted Barnes (Gas Technology Institute)

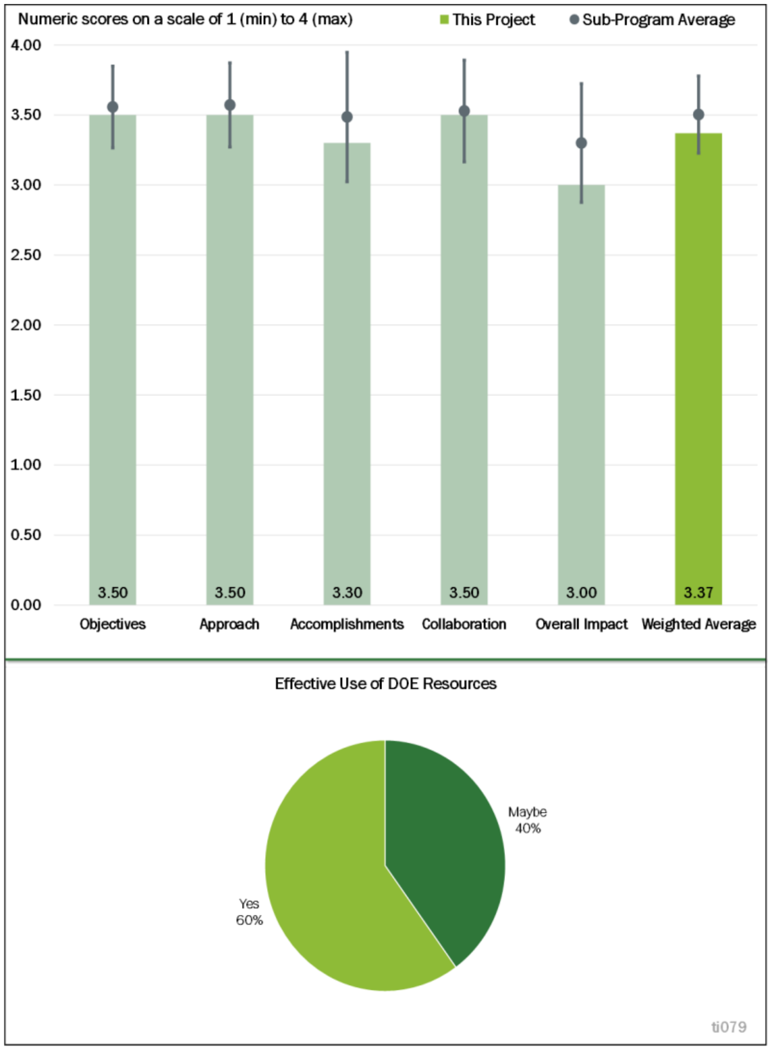

Figure 7-2 - Presentation Number: ti079 Presentation Title: Training for Cost-Effective, Code-Compliant Gaseous Fuel Maintenance Facilities Principal Investigator: Ted Barnes (Gas Technology Institute)

Presenter

Ted Barnes, Gas Technology Institute

Reviewer Sample Size

A total of five reviewers evaluated this project.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer thought the project's training objectives supported the safe use of natural gas, propane, and hydrogen fuels by fleets, and were well-aligned with DOE/VTO objectives.

Reviewer 2:

The reviewer noted that the principal organizer clearly has the technical skill set and the pulse of industry to address all of the issues and concerns that may arise from such training and operational guidance.

Reviewer 3:

The reviewer said that the presentation related broad VTO integration goals to relevant project objectives. From this reviewer's perspective, the objective correctly stated that gaining hands-on experience with facility tours were important elements to addressing the barrier related to consumer lack of technical experience with new fuels. The reviewer added that a compendium of best practices and lessons learned is planned and warranted to have a larger and more lasting impact.

Reviewer 4:

The reviewer asserted that overcoming alternative fuels barriers is important, particularly when it comes to clarifying or explaining compliance with complex regulations or safety codes that may not be well understood because of the lack of trained professionals in the alternative fuels field.

Reviewer 5:

Overall, the reviewer commented that project objectives supported the DOE/VTO objectives of increasing fuel diversity through using alternative fuels and increasing transportation efficiency. However, the project presentation did not emphasize the key objective of "increasing transportation efficiency." The presentation stated that the project seeks to support the DOE/VTO objectives of "increasing national security by reducing barriers to the use of alternative fuels, and promoting economic growth by increasing opportunities related to advanced technology vehicles and affordability for businesses." The reviewer noted that the project objectives were generally effective, but could be improved by including focus on increasing transportation efficiency.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer described the development of best practice documents, training sessions, and follow-on web-based information and training tools as an excellent approach.

Reviewer 2:

The reviewer indicated that the principal investigator (PI) did not recreate the wheel by repeating previous publications; National Renewable Energy Laboratory reports were leveraged instead. The PI worked with NGVAmerica and others to develop training curriculum resulting in excellent training materials that reflected the work of education professionals. This reviewer added that web-based information sources will help ensure the widest dissemination of training materials. Further, the reviewer noted that having only five visits limits the impact that might otherwise have been accomplished with additional training visits.

Reviewer 3:

The reviewer identified the following strengths: executed trainings are targeted and efficiently run; and technical hardware is available for direct handling/hands-on interaction at the trainings.

Reviewer 4:

The reviewer thought that the project approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives was excellent and that the project was well-designed, feasible, and aligned with other DOE/VTO efforts. It was noted that the project focused on three alternative fuels (natural gas, hydrogen, and propane) and the approach featured three distinct phases: material development (developing the technical basis for training materials and creating the training curriculum); training program review, planning, and development (workshop development/planning, dedicated project website, instructor-led training module, video and interactive elements, and instructor guide and student handbook); and training program implementation (establishing and implementing workshop events, establishing web-based information sources, and recording metrics on program success). The project was aligned with Marathon Technical Services to coordinate efforts based on relative strengths. The reviewer suggested that the project approach presentation could be improved by identifying "metrics on program success" and reporting on success to date.

Reviewer 5:

The program was excellent as far as it goes, according to the reviewer. It is desirable to have no-cost training from Marathon Technical Services, a firm that has extensive real-world experience and can provide sage advice on best practices and an appropriate administration of the code requirements. The reviewer also noted that program beneficiaries in the nine cities identified for training will undoubtedly receive invaluable training and advice. The only concern this reviewer expressed is how the information will be disseminated through webinars, websites, and workbook distributions. The reviewer suggested considering continuation of the current hands-on program in additional cities, with the co-sponsorship of other private and public sector organizations and with a more coordinated train-the-trainer outreach. It will be difficult to replicate the success of this program electronically or simply by making the workbooks available, according to the reviewer.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
It was clear to the reviewer that the accomplishments and progress closely track the project work plan to the extent of achieving the identified project milestones.

Reviewer 2:
The reviewer noted that three of five visits have been completed and each appeared to have been a success with good participation. The PI demonstrated flexibility by going from a half-day session with multi-fuels, which this reviewer commented is hard to do, to half-day sessions with a single alternative fuel. The reviewer pointed out that training material was completed in a timely fashion and that website development appeared to be making good progress.

Reviewer 3:
Although work remains to be done, the reviewer believed that this effort is in its early stages and appears on track for achieving objectives.

Reviewer 4:
Strengths according to the reviewer include good geographic distribution of trainings and strong training materials developed by the project. However, as a weakness, the reviewer noted that the six training sessions to be delivered by the project seemed slightly low.

Reviewer 5:
The reviewer thought the project's accomplishments appeared to be generally effective, and that progress is on schedule by meeting its milestones. The project has completed "Codes Reports" and "Keys Issues and Best Practices Reports" for propane, natural gas, and hydrogen, and has developed curriculum plans and training materials (technical reports, educational materials, best practices, and website). It has developed workshop materials, is identifying workshop locations and schedules, and has conducted some workshops. As noted by the reviewer, however, the presentation offered little information or data on activity impacts other than "Workshop and material information sent to thousands of stakeholders; over 3,500 LinkedIn views" on Slide 11. The reviewer would like to have seen the location and number of workshops that have been conducted and will be conducted, the number of workshop attendees, the number of distributed technical reports and educational materials, and the number of website users. The reviewer recommended a more robust listing of impacts to highlight project accomplishments.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The reviewer noted that collaboration in developing guidance materials appeared to have included experts in the industry and was carried out efficiently.

Reviewer 2:
The reviewer described the organization and coordination between the PI, the eight Clean Cities Coalitions, the facilities' operators, and the participating fleet owners as commendable.

Reviewer 3:
The reviewer remarked that the Gas Technology Institute (GTI) could not have picked a better partner on hydrogen expertise than Frontier Energy (California Fuel Cell Partnership). Superior Energy Services (propane) and Clean Energy Fuels (compressed natural gas [CNG]) appeared to this reviewer to be strong

technical organizations with good expertise on those respective fuels. The reviewer pointed out that teaming with Clean Cities has delivered greater outreach locally and regionally, and that the project was active on social media, as evidenced by 3,500 LinkedIn views. This reviewer also observed targeted outreach, as evidenced by authorities having jurisdiction, fire marshals, and code officials attending.

Reviewer 4:
Project collaboration and coordination appeared to be good from this reviewer's perspective. The reviewer noted that the team members and partners appeared to be appropriate and the collaboration appeared to be effective. The key collaborators observed by this reviewer are SMEs in natural gas (Clean Energy Fuels), hydrogen (Frontier Energy), propane (Superior Energy Services), and the Clean Cities coordinators. The reviewer also highlighted, however, that the project presentation did not provide adequate information about roles or detail about the level of involvement for each of these collaborators.

Reviewer 5:
The reviewer noted strengths including Sandia National Laboratories' involvement and participation to bolster the project, and that the project was well-coordinated with a similar, separate VTO-funded project led by Marathon Technical Services. The single weakness reported by this reviewer is the minimal/challenging engagement of local/municipal inspectors in the trainings.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
The reviewer wrote that measuring impact is not possible because the project is in the early stages of conducting training sessions with more work to follow.

Reviewer 2:
The reviewer noted that the developed materials offered an extraordinary resource for the participating stakeholders, but the impact is still largely limited to the reach of audiences in the selected cities. While electronic and print versions of the material will be available, it probably will not have the same impact as the organized workshops where the subject matter can be more effectively presented and explained.

Reviewer 3:
It appeared to the reviewer that the project has already contributed—and will continue to contribute—to increasing fuel diversity through using alternative fuels and increasing transportation efficiency. However, the project presentation offered little information or data on the overall impact of the project activities. According to the reviewer, this type of "impact" information is needed to rate the project's overall impact higher than "good."

Reviewer 4:
Two weaknesses were indicated by this reviewer: it is unclear how proactively the (very good) training materials developed will be disseminated going forward; and the number of executed trainings through the project is somewhat low (six), thus limiting the overall impact without a continuation plan.

Reviewer 5:
This reviewer described two observations as both positives and negatives. Firstly, although the locations receiving the training are being positively impacted, the reviewer commented that the impact of this effort is limited because there are only three locations (and a total of five). Secondly, while the presenter was correct in saying that workers do not have time for three-day training sessions, the impact is limited because of only half-day training. Described as a positive, this reviewer noted that materials made available through a dedicated website will help with dissemination, and thus potentially positively address overall impact.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The project is efficiently tackling an important area with minimal investment from DOE, according to this reviewer.

Reviewer 2:

The reviewer pointed out that the reviewed project is very similar to a separate one led by Marathon. Now that each approach has been piloted, this reviewer suggested the best elements of each be kept and merged into a new, single effort.

Reviewer 3:

This reviewer stated yes; resources are being used wisely for this and the accompanying Marathon project. However, the reviewer was unsure if further investment in the very specific barrier is necessary—the two efforts together may have covered enough regions and will have so-called "trained the trainer(s)."

Reviewer 4:

The reviewer found that funds were utilized wisely, but maximizing the program's value requires updates beyond webinars and a website. The reviewer said that more on-site trainings are required around the country.

Reviewer 5:

To the reviewer, it was not easy to determine whether DOE resources were being leveraged and funds used wisely because the project presentation offered almost no information or data about the overall impact of project activities. The reviewer remarked that this type of "impact" information is needed to determine whether the project is a wise use of DOE resources. Also, it was unclear to the reviewer why DOE funded both this project and project TI080 (Marathon), which appear to have extensive overlap with project TI079 (GTI). (DOE Program Clarification: TI080 [Marathon] and TI079 [GTI] have similar goals and each address the same gaseous fuel safety training need. However, each project has a different approach, training plan, and distinctly different geographic target markets. Project overlap and duplication is minimized by collaboration between the two project teams throughout the performance period. Workshop site locations are chosen to avoid duplication and expand geographic coverage. Technical background materials are shared between teams to promote consistency. This dual training approach was intentional, with the goal of determining which training aspects of each workshop approach are most effective and impactful in actual practice. Lessons learned will inform future training activities going forward and, if successful, possibly lead to expansion of this training to include additional geographic territories.)

Presentation Number: ti080
Presentation Title: Safety Training and Design, Permitting, and Operational Guidance for Gaseous Fuel Vehicle Facilities
Principal Investigator: Rob Adams, (Marathon Technical Services USA)

Presenter

Rob Adams, Marathon Technical Services USA

Reviewer Sample Size

A total of five reviewers evaluated this project.

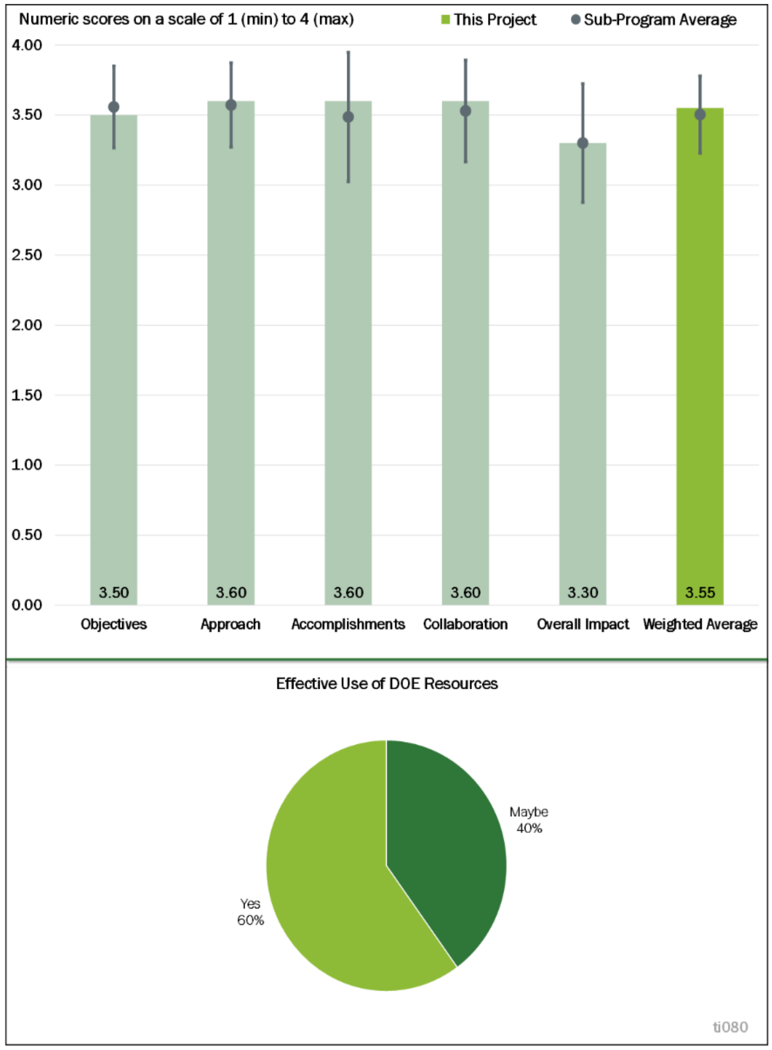

Figure 7-3 - Presentation Number: ti080 Presentation Title: Safety Training and Design, Permitting, and Operational Guidance for Gaseous Fuel Vehicle Facilities Principal Investigator: Rob Adams, (Marathon Technical Services USA)

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer commented that the project objectives were consistent with VTO's goals of energy security, economic growth, and affordability, and could provide needed guidance and training across the natural gas, hydrogen, and propane industries.

Reviewer 2:

The reviewer indicated that the project's training objectives supported the safe use of natural gas, propane, and hydrogen fuels by fleets, and were well-aligned with DOE/VTO objectives.

Reviewer 3:

The reviewer remarked that this project addresses a critical barrier to increasing the use of alternative fuels—understanding how to comply with complex regulatory or safety codes relating to fuels. The need for guidance and education in this area is important because of the newness of alternative fuels and lack of experts.

Reviewer 4:

The reviewer asserted that project objectives align with VTO goals as well as stated barriers. The reviewer noted that upgrading a garage to accommodate gaseous vehicles is a nonstarter for most. Fortunately, it is often not required and this effort could make a difference in informing such a determination. The reviewer pointed out that the project objective to build on past projects avoids a "reinventing the wheel approach" and makes more effective use of resources. The reviewer also reported that the effort intends to reach out to nine metropolitan areas, which is good coverage for a project of this size.

Reviewer 5:

The reviewer thought that overall, the project supported the DOE/VTO objectives of increasing fuel diversity through alternative fuel use and increasing transportation efficiency. However, the DOE/VTO objectives that the project seeks to support, as indicated by the project presentation are the following: national security (safe and cost effective garages encourage transition to domestic gaseous fuels); economic growth (reduced cost will improve monetary viability of projects, which equals more projects); affordability (reduce cost through rigorous, but not excessive, upgrades); and reliability (ensure that garages operate safely, thereby avoiding incidents). Acknowledging that the project objectives are similar to some DOE/VTO objectives, this reviewer pointed out that the project does not emphasize the key objective of "increasing transportation efficiency." Further, the reviewer remarked that the project objectives are generally effective, but could be improved by including focus on increasing transportation efficiency.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer observed careful planning in year 1 for the best sites to visit, which has led to great turnout when executing the workshops. Additionally, this reviewer commented that peer-reviewing the training materials increases the quality of the training delivered. The reviewer also highlighted that the nine sites selected represent a good cross-section of areas with a large presence of industrial garages in the United States.

Reviewer 2:

The reviewer described the project approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives as excellent. The project was well-designed, feasible, and aligned with other DOE/VTO efforts. The reviewer reported that the project focused on multiple alternative fuels (CNG, liquefied natural gas [LNG], propane, and hydrogen) and the approach featured three distinct phases: identification and evaluation of gaseous fuel garages to host training sessions; development of user-friendly training manuals and other materials; and gaseous fuel training sessions in selected garages. The reviewer added that the project aligned with GTI to coordinate efforts based on relative strengths.

Reviewer 3:

The reviewer noted that providing training at no-cost was a good incentive for attendees and a means for building strong training attendance. Also considered a strength by this reviewer were the developed training sessions that involve site visits/tours of host fleet facilities (21 different facilities in all).

Reviewer 4:

The reviewer stated that the approach was well thought-out and suggested that it would be great to add follow-on materials such as video tutorials. Otherwise, this reviewer would not change the approach.

Reviewer 5:

The reviewer remarked that it was notable that GTI worked with Marathon Technical Services to coordinate efforts based on each of their strengths. Conversely, while the scope of projects TI079 and TI080 were different—as were the project partners and geographical locations— the reviewer thought there still seemed to be some replication of effort between the two projects. Nonetheless, the interaction between the two project investigators produced a more comprehensive document than is likely to have been the case otherwise.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:

To the extent of evaluating the project's accomplishments and progress, this reviewer thought the project was well-planned and executed and was producing outstanding, quantifiable results in terms of meeting milestones and achieving outreach goals.

Reviewer 2:

The reviewer highlighted the following strengths: the project is on track to deliver a good number of training sessions; training attendance is good (some have sold out); and the project has developed 18 case studies for a representative sample of garage upgrade projects, which is a very valuable asset to the project and DOE.

Reviewer 3:

The project's accomplishments were described by this reviewer as very effective and on schedule to contribute to project objectives and DOE goals. The project was meeting its milestones, and the presentation provided good information on the impacts of its activities, such as the number of training sessions conducted (and to be conducted), locations of past and future training sessions, types of materials developed, and "legacy impact" beyond year 3.

Reviewer 4:

The reviewer thought that the 18 case studies developed to-date provided a broad amount of coverage across the four alternative fuel types demonstrated at the workshops. The training manuals appeared to be user-friendly with plenty of diagrams and photos to accompany the text. The reviewer also noted that the large amount of interest and attendance generated by the three site visits/workshops in Buffalo, New York; Canton, Ohio; and Columbus, Ohio. This reviewer also reported that the PI mentioned the Buffalo training was sold out.

Reviewer 5:

It was not possible for this reviewer to fully answer this question because the project is still in the early stages with more training sessions and materials to follow at a later time.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:

It was clear to this reviewer that the project was well managed and well-coordinated between the SMEs and Clean Cities Coalitions.

Reviewer 2:

The reviewer noted that the collaboration in developing materials and consulting other experts in the field appeared to have been conducted efficiently and effectively.

Reviewer 3:

Collaboration and coordination on the project appeared to be excellent to this reviewer, who also observed appropriate team members and partners as well as effective collaboration. The key collaborators were Clean Fuels Ohio and several other Clean Cities coalitions. Additionally, the reviewer commented that the project presentation provided good information about collaborator roles and their level of involvement.

Reviewer 4:

The reviewer noted that Marathon was working with Clean Fuels Ohio and several other Clean Cities organizations to coordinate the training. This reviewer further indicated that Marathon and the team identified 21 host fleet facilities to conduct training across the nine cities that will be visited. This increased coordination ensures that all alternative fuels will be covered in each city.

Reviewer 5:

The reviewer highlighted two strengths: the project is well-coordinated with a similar, separate VTO-funded project led by Marathon Technical Services; and the project is effectively partnered with eight Clean Cities Coalitions nationally. Similarly, this reviewer noted the following two weaknesses: minimal and/or challenging engagement with local and municipal inspectors, overall; and engagement with private fleets has been difficult, thus far.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer noted that it appears the project has already contributed, and will continue to contribute, to broadening fuel diversity through alternative fuel use and increasing transportation efficiency.

Reviewer 2:

The reviewer thought that while this effort only involves indoor refueling at industrial garages, the approach and accomplishments maximize the impact that such an effort can achieve given the resources being applied. Clean Fuels Ohio has proven to be an effective partner in communicating with Clean Cities Coalition partners in advance of workshop visits and for general information dissemination. Additionally, the reviewer noted that the case studies prepared for best practice garage upgrades should go a long way toward informing decision makers that are interested in switching to CNG, LNG, hydrogen, or propane for indoor operations.

Reviewer 3:

The reviewer noted that it was early to assess the impact of this program at this stage.

Reviewer 4:

This reviewer stated that one must conclude that the project has been very impactful in terms of the workshops completed, the audiences reached, and the collaborations achieved. However, the reviewer suggested that additional consideration should be given to how the materials developed can continue to be effectively disseminated and updated.

Reviewer 5:

As a strength, the reviewer commented that the developed case studies provide valuable, shared industry best practices for operations from a variety of fleets. Although the project intends for trainings to be replicable, the reviewer observed no clearly-defined means for achieving this. Further, there has been no National Alternative Fuels Training Consortium engagement to date. It also was unclear to the reviewer how proactively developed training materials will be disseminated going forward.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The reviewer commented that the project was tackling an important issue and represents modest investment by DOE.

Reviewer 2:

The reviewer stated yes; resources were wisely applied in this project and the outcomes were very beneficial. Because this and the accompanying GTI project may have achieved an appropriate level of information dissemination, the reviewer was unsure if more projects of this type should be awarded in the future. State, regional, and local officials may be able to use the information and continue the training and awareness into the future.

Reviewer 3:

The reviewer thought the project was very similar to a separate one led by GTI. Now that each approach has been piloted, this reviewer suggested that the best elements of each be kept and merged into a new single effort.

Reviewer 4:

The reviewer suggested that thought should be given to consolidating resources utilized in the development of both this program and TI079 for the purpose of funding additional outreach and hands-on training while assuring that the materials disseminated remain current.

Reviewer 5:

According to the reviewer, it appeared that DOE resources were being leveraged and funds used wisely; DOE probably should fund similar projects in the future. However, it was unclear why DOE funded both this project and project TI079 (GTI), which have extensive overlap with project TI080 (Marathon). For future projects, this reviewer recommended that DOE select one provider to avoid overlaps and duplication of effort. (DOE Program Clarification: TI080 [Marathon] and TI079 [GTI] have similar goals and each address the same gaseous fuel safety training need. However, each project has a different approach, training plan, and distinctly different geographic target markets. Project overlap and duplication is minimized by collaboration between the two project teams throughout the performance period. Workshop site locations are chosen to avoid duplication and expand geographic coverage. Technical background materials are shared between teams to promote consistency. This dual training approach was intentional, with the goal of determining which training aspects of each workshop approach are most effective and impactful in actual practice. Lessons learned will inform future training activities going forward and, if successful, possibly lead to expansion of this training to include additional geographic territories.)

Presentation Number: ti081
Presentation Title: WestSmartEV: Western Smart Plug-In Electric Vehicle Community Partnership for Electric Vehicles and Infrastructure
Principal Investigator: Chad Teply (PacifiCorp)

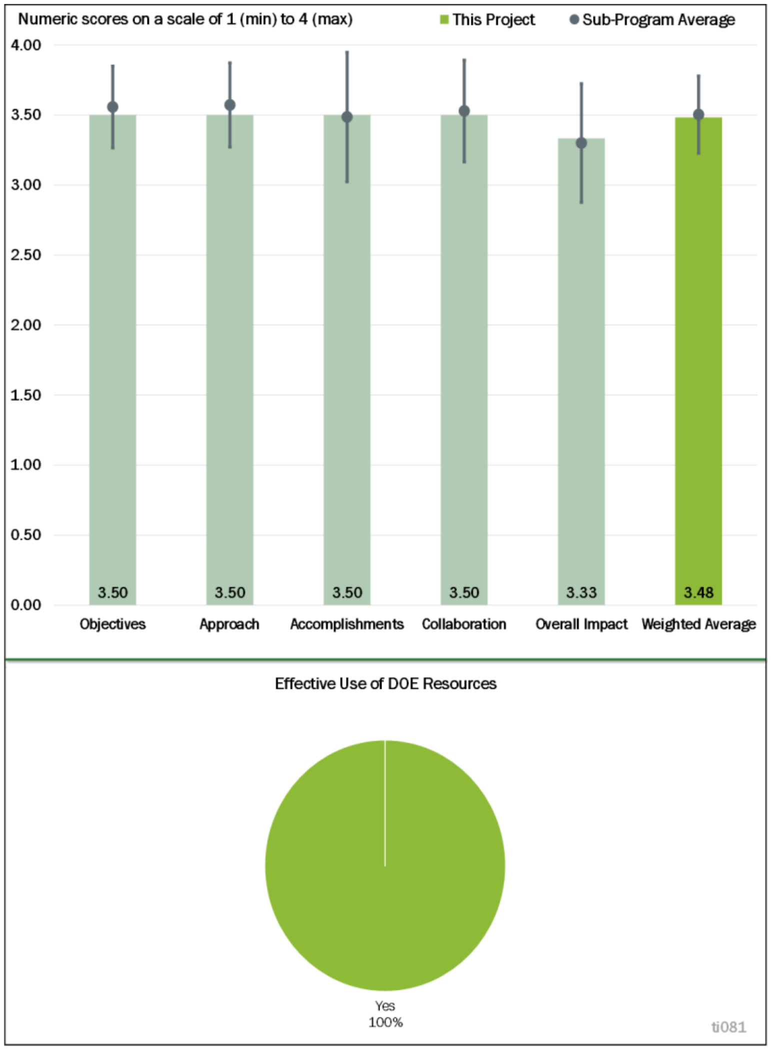

Figure 7-4 - Presentation Number: ti081 Presentation Title: WestSmartEV: Western Smart Plug-In Electric Vehicle Community Partnership for Electric Vehicles and Infrastructure Principal Investigator: Chad Teply (PacifiCorp)

Presenter

James Campbell, PacifiCorp

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer commented that the project objective and overview slides effectively described the project’s specific objectives, as well as how the project supports the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency. The reviewer said that the project addressed several of VTO’s TI goals, such as energy security, economic growth, affordability, and reliability/resiliency through the development of electric vehicle (EV) charging infrastructure along highways (direct-current fast-charging [DCFC]) and at workplace locations (Level 2). This reviewer further indicated that project objectives appeared to be effective for the planned scope.

Reviewer 2:

The reviewer remarked that the project objectives addressed multiple barriers across multiple states.

Reviewer 3:

The project, according to the reviewer, increased diversity by expanding fuel infrastructure, which is a critical gap area. This reviewer also highlighted the high value for deployment focus, and noted that only a single fuel (electricity) was selected with the project covering a limited geographic area. The reviewer opined that additional work is needed for diversity of fuels and geographies present in the United States.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer thought the project approach section provided an effective methodology to accomplishing the project objectives and supporting the integration of advanced transportation technologies and practices. All six of the project tasks were well-aligned in providing a comprehensive approach to the goal of increasing EV market penetration through the development of corridor and workplace charging. The reviewer observed adequate detail provided on the approach and milestone slides with regard to the planned tasks and activities.

Reviewer 2:

The reviewer explained that the approach resulted in a number of states and stakeholders coming together to build-out the infrastructure for EV corridors.

Reviewer 3:

The reviewer noted that the project expanded DCFC stations, Level 2 stations, and vehicles through incentives.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:

According to the reviewer, very effective progress has been made towards achieving project goals. All pilot phase milestones have been completed and the expansion phase milestones were all underway. The reviewer reported that 20 of 65 DCFC chargers and 343 of 600 Level 2 workplace chargers have been installed. Additionally, charger location analysis, charger utilization data analysis, and the smart mobility activities appeared to be on track for successful completion. This reviewer further stated that no concerns have been identified.

Reviewer 2:

The reviewer noted that this project resulted in a multi-state memorandum of understanding to develop EV corridors and that the use of EVs has doubled in the region since the inception of this program.

Reviewer 3:

The reviewer reported that it is early in project, and also highlighted model and initial integration progress.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:

Team collaboration and coordination appeared to result in very good results from this reviewer’s perspective. The inclusion of the University of Utah’s University Transportation Center was beneficial to the program.

Reviewer 2:

The reviewer observed an effective project team assembled to execute this project, with industry and Clean Cities coalition partners involved, which provides an excellent mix of expertise among team members. The project team roles were defined and collaboration/communication among project partners appeared to be appropriate for the project scope. Additionally, this reviewer pointed out that the project partnered with state agencies, infrastructure providers, local non-profits, and industry advocacy groups.

Reviewer 3:

The reviewer would like to see more progress reported from Clean Cities coalitions in the project area, as well as a system for lessons learned and repeatability beyond the project area.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

As mentioned in prior comments, this reviewer explained that the project had significant impacts and brought together several states to coordinate efforts and resources to build-out the EV infrastructure network across multiple states.

Reviewer 2:

The reviewer asserted that the project was effective in contributing to increasing fuel diversity through alternative fuel use and increasing transportation efficiency. The project contributed to electrifying the I-15 corridor in Utah and indirectly supported the doubling of the number of EVs in the state. Additionally, this reviewer reported that PacifiCorp committed to a continued investment of $2 million per year for 2 years beyond the project period of performance. Finally, the reviewer added that the project efforts have contributed to the electrification of six buses in the Park City transit fleet.

Reviewer 3:

The reviewer remarked that the project advances DCFC and Level 2 EVs for the project area, but 65 DCFC and 600 Level 2 vehicles will only be a fraction of what is needed to service 50,000 EVs. Far more community partnerships and leverage must be identified. The reviewer suggested reviewing the cost of gasoline compared with the cost of electricity in the project area. The reviewer thought that chargers may see more use, or consumers may be more interested in vehicles, if costs were lower than gasoline, or if there were times when costs would be lower than grid costs at home.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

This reviewer opined that the use of DOE funding to develop highway corridors and workplace charging is a critical strategy/activity to advancing the EV market. The projects that support implementation strategies and activities, such as barrier removal, should assist with market transformation in the local/regional target area. Additionally, the reviewer commented that smart mobility and data analysis activities are an important project component that can provide lessons learned to other adopters as well as provide critical data to industry, decision makers, and government/national laboratories.

Reviewer 2:

The reviewer stated that the use of resources was efficient and resulted in data that could be used by other areas/regions around the country to replicate the program.

Reviewer 3:

The reviewer indicated that the project shows the high value of technology integration and installation in a project area and that similar projects should consider a nationwide application. Good use of Clean Cities coalitions was observed by this reviewer, who suggested that numerous other geographies could benefit from similar corridor projects run in collaboration with Clean Cities and utilities. The reviewer explained that 65 DCFC and 600 Level 2 are inadequate for high market levels of EV adoption, and asserted that far more resources must be dedicated to this deployment. This reviewer further suggested that other fuels be deployed in supported partnerships by DOE to help secure our energy, economic, and environmental futures.

Presentation Number: ti082
Presentation Title: U.S. Fuels Across America's Highways—Michigan to Montana (M2M)
Principal Investigator: Ted Barnes (Gas Technology Institute)

Presenter
Ted Barnes, Gas Technology Institute

Reviewer Sample Size
A total of three reviewers evaluated this project.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

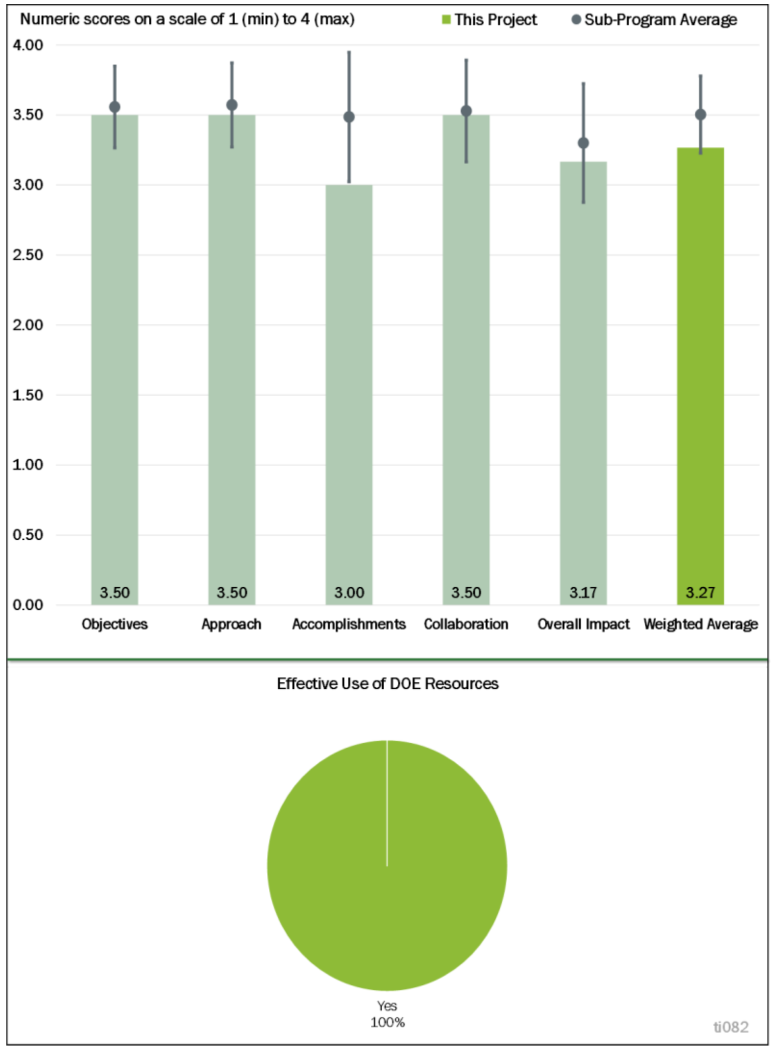

Figure 7-5 - Presentation Number: ti082 Presentation Title: U.S. Fuels Across America's Highways—Michigan to Montana (M2M) Principal Investigator: Ted Barnes (Gas Technology Institute)

Reviewer 1:
The reviewer noted that the lack of infrastructure for alternative fuels continues to be a barrier that impedes deployment of alternative fuel vehicles (AFVs). In areas where stations have not been deployed and incentives are not strong, it can be difficult to get stations installed, therefore it takes a collaborative effort to identify stakeholders including fleets or users that will buy vehicles that can refuel at new stations. The reviewer commented that this is a worthwhile effort to address shortcomings in key areas of the country where no one entity can address all the issues involved.

Reviewer 2:
The reviewer explained that the project objective and overview slides describe the project's specific objectives, as well as how the project supports the DOE/VTO objectives of increasing fuel diversity through alternative fuel use and increasing transportation efficiency. The project addresses several VTO TI goals, such as energy security, economic growth, affordability and reliability/resiliency, through the development of alternative fuel infrastructure (EV, CNG, and propane) along the I-94 highway corridor from Michigan to Montana. The project objectives appeared generally effective for the planned scope from this reviewer's perspective.

Reviewer 3:
The reviewer remarked that the project's objectives lined up nicely with the Federal Highway Administration's (FHWA) Alternative Fuels Corridor Program—a multi-alternative fuel initiative (EV, CNG, and propane) to build-out infrastructure on I-94 from Billings, Montana to Port Huron, Michigan, to create a sustainable alternative fuels corridor.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:
The reviewer stated that the project approach appears to be well-conceived.

Reviewer 2:
The reviewer noted that the project approach section provided an effective methodology for accomplishing project objectives and supporting the integration of advanced transportation technologies and practices. Adequate details were also provided with regards to planned tasks and activities on the approach slides. The reviewer pointed out that presentation highlighted additional efforts and opportunities leveraged by the project, such as the FHWA Alternative Fuels Corridor designation initiative.

Reviewer 3:
The reviewer remarked that the approach required significant effort to coordinate on-location infrastructure, signage needs, and data collection.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
Because this project is in an early stage of development with two more years to go, this reviewer stated that the accomplishments are good.

Reviewer 2:
According to the reviewer, once the scalability of various alternative fuel infrastructure is achieved, this project will be a model for other areas in the country looking to build-out alternative fuel infrastructure along interstate corridors. The focus on economic growth and reliability/resiliency of alternative fuel infrastructure will provide much-needed information/data for other areas of the country looking to implement similar efforts.

Reviewer 3:
The reviewer observed adequate progress made towards achieving project goals, and noted that vehicle deployment, infrastructure planning, and outreach/training activities were underway. This reviewer reported that 30 CNG long-haul trucks (of the 60 planned) have been deployed. While the planning efforts are underway, slower progress has been made regarding fueling infrastructure development because none of the 15 planned sites have been completed yet. While the reviewer had no significant concerns identified, the reviewer had difficulty determining exactly how actual progress should be measured against the project plan due to the absence of a milestone table in the presentation.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The reviewer was impressed with the degree of collaboration and coordination between the public and private sectors to implement this project.

Reviewer 2:
The reviewer observed an effective project team assembled to carry out this project and lauded the excellent mix of expertise of team members involved from industry and Clean Cities coalition partners. Team members

are well-suited to the project work and the working relationships appeared to be appropriate for a project of this scope.

Reviewer 3:
This reviewer commented that a strong team for success appears to have been put in place.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
The reviewer thought that the project's overall impact will be significant and serve as an excellent case study for other areas of the country working on building out alternative fuel infrastructure along interstate corridors.

Reviewer 2:
The reviewer noted that the project has good potential to contribute to increasing fuel diversity through alternative fuel use and increasing transportation efficiency by deploying alternative fuel infrastructure along the highly traveled I-94 corridor in the Midwest. By focusing on installing electric, CNG, and propane fueling sites, this project will be able to address critical fueling needs for different vehicle/fueling technologies and all classes of vehicles (light-, medium-, and heavy-duty).

Reviewer 3:
Given where the project team is in development, this reviewer described overall impact as good.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:
The resources appeared, to the reviewer, to be efficiently used and will hopefully result in the funding of other corridor projects throughout the country.

Reviewer 2:
The reviewer believed that the project addresses an important issue and is a good use of DOE's funding because there are relatively few deployment programs and fewer that focus on fueling infrastructure.

Reviewer 3:
Using DOE funding to develop highway corridors and adjacent community fueling infrastructure is a critical strategy/activity to advance the market of all alternative vehicles, according to the reviewer. These projects that support implementation strategies and activities, such as barrier removal, should assist with market transformation in the local/regional target area.

Presentation Number: ti083
Presentation Title: Midwest EVOLVE (Electric Vehicle Opportunities: Learning, Events, Experience)
Principal Investigator: Lisa Thurstin (ALA of Upper Midwest)

Presenter
Lisa Thurstin, ALA of Upper Midwest

Reviewer Sample Size
A total of four reviewers evaluated this project.

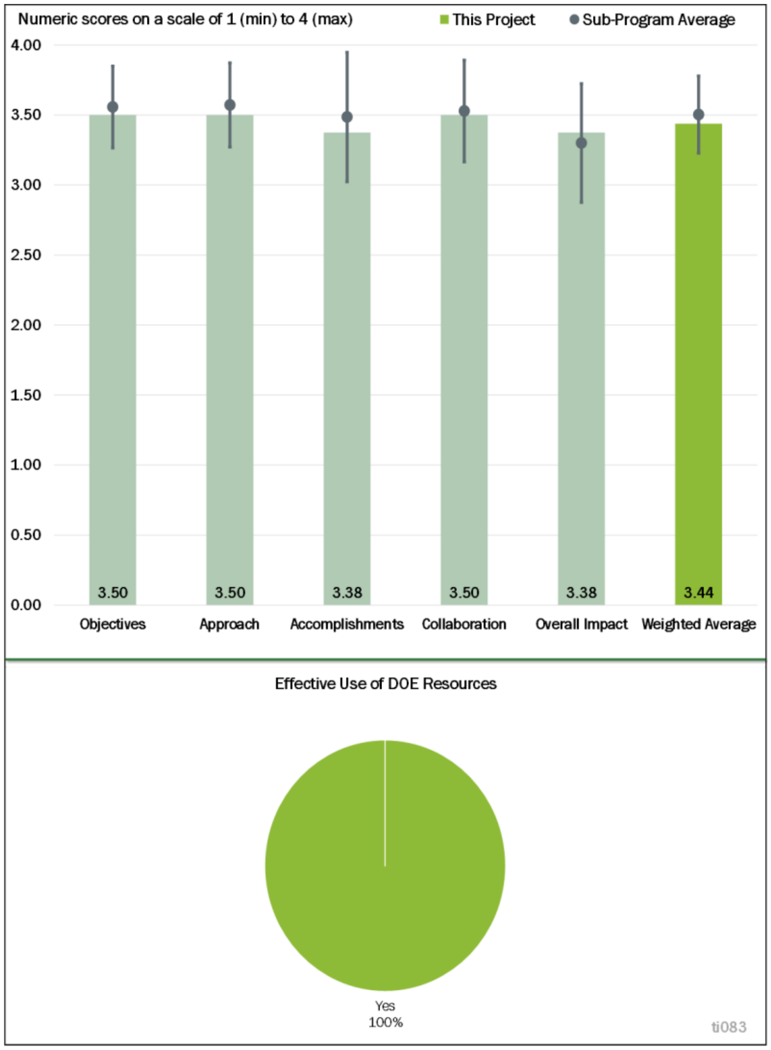

Figure 7-6 - Figure 7-7 - Presentation Number: ti083 Presentation Title: Midwest EVOLVE (Electric Vehicle Opportunities: Learning, Events, Experience) Principal Investigator: Lisa Thurstin (ALA of Upper Midwest)

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
The reviewer noted that the project objectives were focused on the education of both consumers and dealerships to help overcome perceptions about new technologies. The reviewer indicated that they addressed several VTO goals and the identified barrier, “consumer and fleet reluctance to purchase new technologies.”

Reviewer 2:
This reviewer thought the project pulled together a significant portion of the Midwest states to provide education about EVs and expanding fuel diversity.

Reviewer 3:
The reviewer remarked that the project was aimed at understanding and reducing barriers to alternative fuel use in the Midwest, and was well-aligned with DOE/VTO objectives.

Reviewer 4:
Like similar projects, the reviewer indicated that this one had a clear objective to get interested consumer and fleet buyers behind the wheel for real-world experience in EVs.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer noted that the project approach was solid and well-rounded with a good mix of events and venues. Including dealership training and establishing an EV Owner's Forum to enlist current EV owners as technology ambassadors could reap ancillary benefits as well.

Reviewer 2:

This reviewer reported that the approach included large, small, and workplace events combined with survey and data collection to achieve the goals of providing hands-on experience and demonstrating EV use. The project was developing outreach materials to help educate dealers and utilities, which the reviewer believed is a key piece of EV adoption. In conclusion, this reviewer described the approach as effective.

Reviewer 3:

The reviewer remarked that the project successfully pulled together partners and consumers for EV experiences, education, and analysis through surveys.

Reviewer 4:

The reviewer identified two strengths: the project is cooperating with ANL to track EV sales across the Midwest, which is a key approach for measuring project effectiveness; and the project provides valuable dealer training, including an online dealer information forum that has been developed and enables EV owners to provide valuable dealer reviews and ratings.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:

The reviewer was impressed with the accomplishments achieved at the approximate halfway point. The team was only required to hold 8 events in Budget Period 1, but completed 35. The project was on track to meet goals for events over the course of the project. The project team also developed the EVolution tool that helps guide consumers purchasing EVs. With 2,300 test drives completed and 2,400 surveys collected, this reviewer explained that the project team was making progress on ensuring the ability to collect surveys from a majority of participants, which can be a challenge.

Reviewer 2:

The reviewer indicated that the project appeared to be on schedule to meet its goals. Extra events were held and relevant data were collected, indicating an increase in positive perception of EVs.

Reviewer 3:

The reviewer noted that the project was making full progress on all milestones for Budget Period 1. The reviewer was aware of project successes through EV media and the project's nationwide marketing initiative, and asserted that 2,300 test drives is an impressive metric success.

Reviewer 4:

The reviewer saw as a strength how the project has delivered a substantial number of deliverables—2,400 surveys, 2,300 test drives—at 50% project completion. The reviewer identified the following weaknesses: a total number of targeted ride-and-drives—in total and by state— has not been set; extended-test drives have been challenging due to lack of available demonstration EVs in the Midwest; and survey results indicate only 13% of test drive event attendees had never experienced an EV before, which suggests that these events are not targeting a large number of uninitiated people new to the technology.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:

The reviewer saw clear evidence of high levels of collaboration among the project team, shown by the impact of project events and diversity of program partners and locations.

Reviewer 2:

The reviewer noted that the project appeared to have assembled a strong team of partners with a variety of Clean Cities coalitions signing on and actively participating.

Reviewer 3:

Two project strengths were noted by this reviewer: the project involves a large number of robust partnerships, and partners are strongly leveraged (helping the project thus far spur 130 additional events not funded by the project); and the project is effectively partnered with six Clean Cities coalitions across the Midwest.

Reviewer 4:

The reviewer thought that the official project partners were a bit unclear. However, it looked like the Clean Cities coalitions and the project lead were working well together and engaging many other stakeholders in the region.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer commented that the driver experience was a metric clearly showing the impact and an opportunity to expand impact. This reviewer also described 50,000 event attendees as a positive engagement metric. Clearly, choices of macro and micro events have been successfully operationalized to have high overall impact, and this reviewer further asserted that experience data collected from project participant survey metrics was great.

Reviewer 2:

The reviewer noted that the impacts had increased engagement from dealerships and workplaces who were interested in adding charging stations. Both of these impacts are helping to overcome the lack of infrastructure in the region and a lack of vehicles, which are identified barriers. This reviewer added that surveys have also shown an increase in EV appreciation, which is helping to change perceptions.

Reviewer 3:

The reviewer stated that the project had decent impact, noting the large number of participants having experienced EVs through the various drive events. Holding drives in conjunction with large auto-related events like the Chicago Auto Show seemed to be an ideal way to attract interested auto consumers. The reviewer remarked that the exit surveys indicated that the drive programs were effective in positively changing perceptions.

Reviewer 4:

No comments regarding overall impact were noted from this reviewer.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The reviewer thought this project was an excellent use of DOE resources. The hands-on experience was a great way to change people’s impression of any new technology, and the project has shown strong results.

Reviewer 2:

This reviewer indicated that the project is a good use of VTO resources that helps to increase EV adoption and achieve VTO goals. Additionally, the reviewer pointed out that DOE will have information from the surveys as well, which will help in future projects.

Reviewer 3:

The reviewer asserted that the project could be repeated elsewhere and stated that there is a clear need. Examples of future projects suggested by this reviewer could be to continue in project areas as new models are available, or expand into other U.S. regions that could benefit from electric-powered vehicles or other alternative fuels.

Reviewer 4:

The reviewer noted that the project addressed important VTO objectives. Future similar projects, according to the reviewer, should strive to have strong OEM/dealer involvement, and should heavily target audiences with no EV experience or exposure (in addition to those with greater EV familiarity and higher likelihood of purchasing).

Presentation Number: ti084
Presentation Title: Northwest Electric Vehicle Consumer Showcase
Principal Investigator: Jeff Allen (Drive Oregon [Forth])

Presenter

Zach Henkin, Drive Oregon (Forth)

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer remarked that the EV project moves diversity forward by one additional fuel, and that such education objectives are critical to the fuel diversity goal. Lack of awareness and technical expertise for AFVs is a critical area of approach. Additionally, great strategy and goals were observed by this reviewer.

Reviewer 2:

The reviewer noted that the project is aimed at increasing EV use in the Pacific Northwest, and is well-aligned with DOE/VTO objectives.

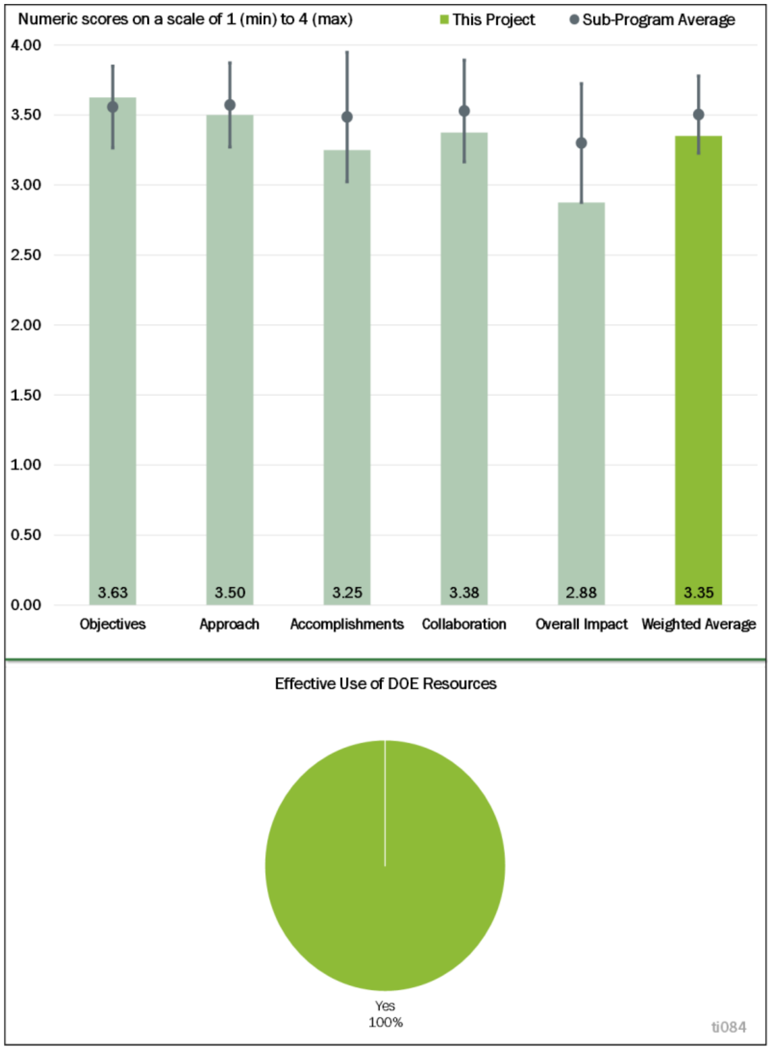

Figure 7-8 - Presentation Number: ti084 Presentation Title: Northwest Electric Vehicle Consumer Showcase Principal Investigator: Jeff Allen (Drive Oregon [Forth])

Reviewer 3:

The project objectives tie directly to VTO goals by focusing on reducing reliance on oil and developing awareness to increase adoption.

Reviewer 4:

The reviewer commented that the project has clear, attainable objectives with measurable results; a multi-faceted approach with physical, virtual, and mobile components; and an innovative EV showroom education center that is unique among similar projects. Providing drive opportunities was described by this reviewer as an excellent approach for influencing people's opinion of EVs, and if steady traffic can be achieved, the EV showroom has potential for great educational opportunities. Although the low- and moderate-income campaign was unique, the reviewer was not sold on its potential effectiveness, given the relatively high cost of some EVs compared to conventional vehicles typically purchased by low- to moderate-income consumers. The utility engagement component shows promise, and the use of leased vehicles for test drives ensured vehicle availability.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer remarked that the downtown EV showcase/showroom keeps four to six vehicles available for inspection and test drives on a daily basis, which is a very good number.

Reviewer 2:

This reviewer described the project as well-defined, and asserted that physical, mobile, and virtual are important strategies. Including data collection and questionnaires allows the analysis of experience and feedback cycles. The reviewer further commented that the project approach aligns with EV experience and education needs, locally and nationwide.

Reviewer 3:

The reviewer opined that the Portland, Oregon EV showroom is an extremely effective approach for education and outreach. It is a really innovative idea, has proven to be effective, and is being replicated in other cities around the country. This reviewer described the ride and drives and online tools as effective for achieving project objectives.

Reviewer 4:

The reviewer stated that the ride and drive concept was a solid base for this project because it had been proven effective elsewhere. Some elements of this program offered unique or innovative approaches for reaching new types of consumers, but did not appear to have as much potential for success. The EV showroom in downtown Portland is well-situated geographically and demographically, but it was unclear to the reviewer that there was a strong strategy in place to get consumers into the showroom other than grabbing passersby off the sidewalk. The reviewer also noted that the presentation did not make clear what those consumers could actually do once inside the showroom.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:

The reviewer reported that the project has achieved all of its Budget Period 1 goals and is progressing on-time with Budget Period 2 goals. The reviewer pointed out that it only took six months to set up the EV showroom, which is very efficient, and that the team has a good rate of survey completions—over 50%—for the ride and drives.

Reviewer 2:

The reviewer noted that the project has made full progress on Budget Period 1 and is making impressive progress into Budget Period 2. It was very significant to this reviewer that the facility and vehicles have been secured and that experiences are underway. The physical showcase is visible not just to Oregon, but also to the nation. The pop-up showcases progress was also described by this reviewer as significant.

Reviewer 3:

The reviewer indicated that the project appeared to be on pace to meet its stated objectives, with several milestones checked off, though some appeared to be easier “low-hanging fruit.” For instance, 2,500 visitors to the EV showroom does not seem like a lot for being in such a prominent location. The reviewer commented that the number of test drive events might be lagging behind the progress of other similar projects.

Reviewer 4:
One challenge noted by the reviewer—not by any fault of the project—is that Oregon's EV rebate is not yet in place.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
The reviewer noted that this project gathered a good team who can provide all the required expertise. Clean Cities coalitions are good outreach partners to ensure fleets are engaged, and a consultant providing communication services elevates the public relations professionalism of the project. Lastly, this reviewer remarked that including a partner with ties to utilities is an effective strategy to engage that sector.

Reviewer 2:
The reviewer observed a strong coalition of diverse partners, but a smaller number of partners than projects of similar budget size and scope. The project team seemed to have had good success enlisting staff for the EV showroom.

Reviewer 3:
As observed by the reviewer, the numerous collaborators were working well together and made good use of Clean Cities coalitions for fleets. Engaging additional Clean Cities coalitions could have integrated more geographies or consumer markets that could be helpful for information sharing later in the project. The reviewer described weekly relationships with dealers as significant and valuable.

Reviewer 4:
The reviewer noted as a strength that the project has engaged 135 utilities to date. However, dealer engagement has been spotty throughout the project. The reviewer opined that this is an area that needs focused attention and work.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
The reviewer noted that the team was tracking vehicle identification numbers to understand the sales impact and saw a 23% growth rate from last year, which is a good improvement that has the team on track to meet its goals. The reviewer reported that the project team's EV showroom is also being replicated, which shows an impressive impact even before the project ends.

Reviewer 2:
EV use in the Pacific Northwest has steadily advanced and increased, though it was not entirely clear to the reviewer how to assess the project's impact on that growth.

Reviewer 3:
The reviewer thought the presentation was unclear if a 23% increase in vehicle sales growth was a goal, was even related to project, or was only related to active state vehicle incentives. EV sales growth nationwide appeared to have been 26% nationwide, and was 36% between 2015 and 2016—both of which appear higher than the project period report. The reviewer suggested that perhaps other metrics may be more appropriate to gauge impact of test drives or experiences. Other states are already taking advantage of lessons shared in the Pacific Northwest experience center, which this reviewer described as wonderful.

Reviewer 4:

The reviewer commented that the project still has some work to complete all of its objectives, so it may be too soon to measure the program's impact. The number of delivered test drives and completed surveys is low compared to other projects, but the project team noted a good increase in the number of EV sales through group buys.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:

The reviewer thought the project is a good use of DOE funds as it has an interesting approach with unique elements. When more milestones are achieved, this reviewer believed it will deliver good value for DOE's investment and will be an effective tool for demonstrating EVs and for positively influencing people's perceptions of them.

Reviewer 2:

The reviewer described this project as an appropriate use of resources that has tested new ways to engage consumers and achieve VTO goals.

Reviewer 3:

The reviewer remarked that this project's goals, collaborations, and accomplishments represent something that is needed in all corners of the United States. This reviewer described the EV showroom, pop-up, and content planning to be shared as potentially very valuable, and that other state partnerships on electricity or other consumer fuels could be highly valuable for VTO goals.

Reviewer 4:

The reviewer had no noted comments on the use of resources.

Presentation Number: ti085
Presentation Title: Advancing Plug-In Electric Vehicle Adoption in New England through Events and Outreach
Principal Investigator: Joel Levin (Plug-In America)

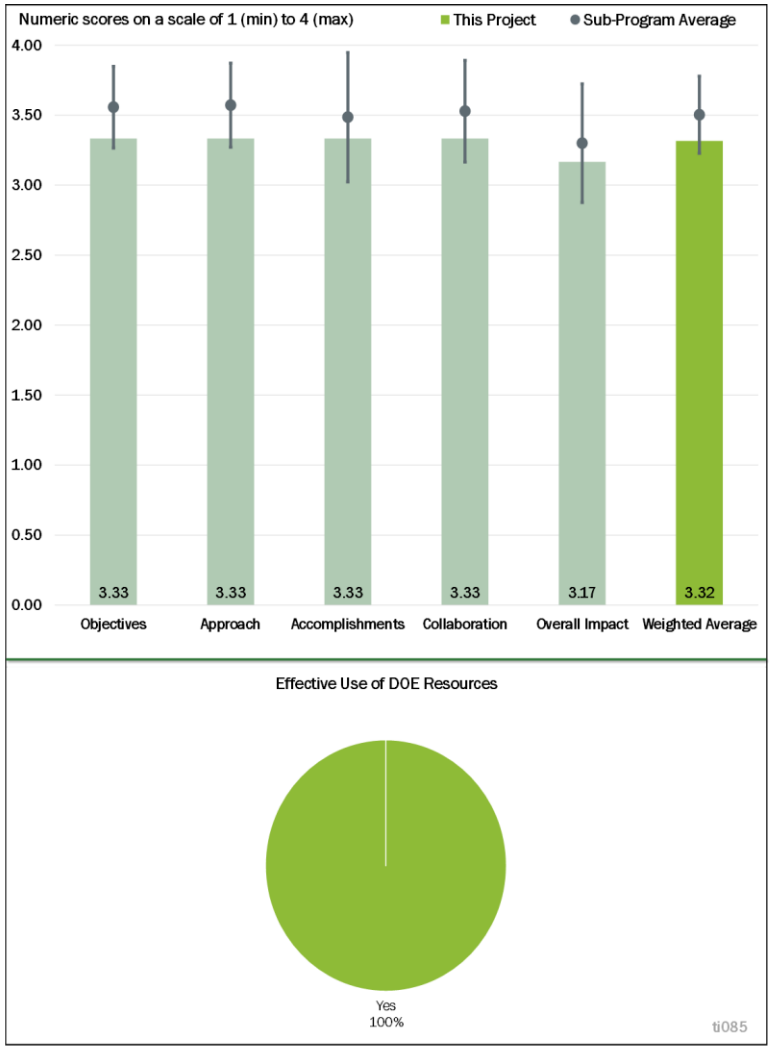

Figure 7-9 - Presentation Number: ti085 Presentation Title: Advancing Plug-In Electric Vehicle Adoption in New England through Events and Outreach Principal Investigator: Joel Levin (Plug-In America)

Presenter

Eric Cahill, Plug-In America

Reviewer Sample Size

A total of three reviewers evaluated this project.

Question 1: Project Objectives—the degree to which the project objectives support the DOE/VTO objectives of increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:

The reviewer asserted that the project objectives are solid and in line with stated DOE goals. The formula of introducing interested or curious consumers and fleet managers to EVs through personalized test drives is solid and should yield good results. This reviewer further explained that educating dealers and creating a replicable blueprint for hosting drive events are unique project objectives and show a well-conceived plan that addresses the issue from multiple fronts.

Reviewer 2:

The reviewer commented that the project objectives directly relate to DOE VTO goals by increasing alternative fuel use and reducing petroleum use.

Reviewer 3:

The reviewer noted that the project objectives were to educate dealers on EVs and expose consumers to them through ride and drives. It was somewhat unclear to this reviewer whether the objectives were achieved.

Question 2: Project Approach to supporting the integration of advanced transportation technologies and practices to support overall project objectives—the degree to which the project is well-designed, feasible, and aligned with other efforts.

Reviewer 1:

The reviewer liked that the project placed additional emphasis on educating dealers to effectively market and sell EVs. The reviewer opined that this element is somewhat overlooked in other projects and makes good sense because an educated dealer is perhaps more important to adopting EV use than just creating demand or consumer interest. The presenter demonstrated a depth of knowledge in how the traditional dealership system is set up and how to address the introduction of a disruptive “new” product into the sales mix.

The reviewer explained that the project also has strong elements of consumer engagement through test drives at public and workplace venues, and gives consideration to data collection, recognizing the better quality of pre-and-post-drive data that can be collected through workplace drives. Another strong element noted by the reviewer was creating a replicable model for other organizations to host drive events. Overall, this reviewer observed a well-conceived project that should achieve great value for the investment.

Reviewer 2:
The reviewer indicated that showcases for the public, fleets, and at workplaces are raising regional awareness and inspiring consumers to consider an EV. Developing dealership training was described by this reviewer as a good way to raise awareness and, based on the project team’s experiences, it appeared that the project team is adjusting its approach to work best with dealers for the remainder of the grant.

Reviewer 3:
The reviewer thought the project approach seemed to be well thought-out and detailed, but was unsure if the execution resulted in intended objectives.

Question 3: Project Accomplishments and Progress toward overall project and DOE objectives and goals—the degree to which progress/significant accomplishments have been achieved, measured against performance indicators and demonstrated progress toward project objectives and DOE goals.

Reviewer 1:
The reviewer noted that the project was on pace to meet or exceed its goals for the number of ride and drive experiences. The dealership training was well-received and resulted in dealers asking for additional training. Survey results also indicated a significant increase in positive perception of EVs.

Reviewer 2:
This reviewer described ride and drive participation as great, but commented that the survey collection rate could be higher. The project had over 1,513 ride and drive experiences but only collected 555 pre-drive surveys and 317 post-drive surveys. Data collection is important so the project team can understand the impact. The reviewer asserted that the best practices guide for showcases is a good resource that has been created, and that the project teams’ work with dealerships is great progress. The surveys from the dealers are very effective and can help inform activities during Budget Period 3 and beyond.

Reviewer 3:
The reviewer believed a larger baseline was needed to measure results, and that completing the “Best Practice” guide will help document project successes.

Question 4: Collaboration and Coordination Among Project Team—the degree to which the appropriate team members and partners are involved in the project work and the effectiveness of the collaboration between and among partners.

Reviewer 1:
This reviewer remarked that the project team seemed very well organized and knowledgeable about the regional auto marketplace. The reviewer also noted that it had delivered an impressive number of test drives for a relatively small project, which was a testament to the organizational strength and active partner participation.

Reviewer 2:
The project collaboration seemed appropriate for the scope from this reviewer's perspective. The reviewer also commented that the Clean Cities coalitions have good contacts, and adding additional partners throughout the state and industry helped to broaden reach.

Reviewer 3:
The reviewer indicated that collaboration and coordination between the project lead and dealerships seemed to work well.

Question 5: Overall Impact—the degree to which the project has already contributed, as well as the potential to continue to contribute in the future, to increasing fuel diversity through the use of alternative fuels and increasing transportation efficiency.

Reviewer 1:
The reviewer asserted that this project conducted an impressive number of test drive experiences, collected some meaningful data, and contributed guidance to assist future projects in replicating success. That alone was noteworthy to this reviewer, who added that the impact of this project is effectively extended for years to come when combined with the drive programs.

Reviewer 2:
The reviewer noted that dealership trainings are currently focused in Massachusetts and could be broadened to include the other states in the region. Also, this reviewer suggested that the team should focus on collecting the ride and drive surveys to ensure data are available to support project outcomes.

Reviewer 3:
The reviewer believed the overall impact will be useful, but noted that the baseline needs to be larger to fully measure impacts.

Question 6: Use of Resources. Are DOE resources being leveraged and funds being used wisely? Should DOE fund similar projects in the future?

Reviewer 1:
The reviewer described a well-conceived and strongly managed program with multiple facets, some of which are unique to this program. The number of test drives was impressive for the relatively small DOE investment, and the replicable model for duplicating the project team's success should help future projects make even better use of DOE resources.

Reviewer 2:
The reviewer agreed that the project is a good use of DOE resources. Dealer education about alternative fuels is very important and continued consumer education through ride and drives is a worthwhile use of resources.

Reviewer 3:
This reviewer observed a good use of resources, but suggested giving more thought to measuring intended results.

Acronyms and Abbreviations

ADAS	Advanced driver assistance system
AFDC	Alternative Fuels Data Center
AFV	Alternative fuel vehicles
ANL	Argonne National Laboratory
AVTC	Advanced Vehicle Technology Competitions
CNG	Compressed natural gas
DCFC	Direct-current fast-charging
DOE	U.S. Department of Energy
FHWA	Federal Highway Administration
GM	General Motors
GTI	Gas Technology Institute
kWh	Kilowatt hour
LNG	Liquefied natural gas
M2M	Michigan to Montana
NSF	National Science Foundation
OEM	Original equipment manufacturer
PI	Principal Investigator
R&D	Research and Development
SME	Subject matter expert
STEM	Science, technology, engineering, and math
TI	Technology Integration
VTO	Vehicle Technologies Office

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8. Vehicle Analysis

To strengthen national security, enable future economic growth, support energy dominance, and increase transportation energy affordability for Americans, the Vehicle Technologies Office (VTO) funds early-stage, high-risk research. The research will generate knowledge that industry can advance to deploy innovative energy technologies to support affordable, secure, reliable and efficient transportation systems across America. VTO leverages the unique capabilities and world-class expertise of the national laboratory system and works with partners across industry and academia to develop new innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures and better powertrains; and energy efficient mobility technologies and systems, including connected and automated vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement. VTO is uniquely positioned to address early-stage challenges due to its strategic research partnerships with industry (e.g., the U.S. DRIVE and 21st Century Truck Partnerships) that leverage relevant technical and market expertise. These partnerships prevent duplication of effort, focus U.S. Department of Energy (DOE) research on the most critical research and development (R&D) barriers, and accelerate progress. VTO focuses on research that industry either does not have the technical capability to undertake on its own—usually because there is a high degree of scientific or technical uncertainty—or it is too far from market realization to merit sufficient industry emphasis and resources.

The VTO Analysis (VAN) subprogram provides critical information and analyses to prioritize and inform Vehicle Technologies research portfolio planning through technology-, economic-, and interdisciplinary-based analysis, including target-setting and program benefits estimation. The subprogram also supports integrated and applied analyses that bring together useful findings and analysis of the energy impacts of transportation systems through the integration of multiple models including vehicle simulation, traveler behavior, and energy accounting of the entire system. The result creates holistic views of the transportation system, including the opportunities and benefits that advanced vehicle technologies create by strengthening national security, increasing reliability, and reducing costs for consumers and businesses. Overall, VAN activities explore energy-specific advancements in vehicles and transportation systems to inform Vehicle Technologies' early-stage research and offer analytical direction for potential and future research investments.

Subprogram Feedback

DOE received feedback on the overall technical subprogram areas presented during the 2018 Annual Merit Review (AMR). Each subprogram technical session was introduced with a presentation that provided an overview of subprogram goals and recent progress, followed by a series of detailed topic area project presentations.

The reviewers for a given subprogram area responded to a series of specific questions regarding the breadth, depth, and appropriateness of that DOE VTO subprogram's activities. For the 2018 VTO AMR, the VAN subprogram presentation (VAN000) was evaluated against a different criteria as compared to the other R&D subprogram areas. It should be noted that no scoring metrics were applied.

Responses to the subprogram overview questions are summarized in the following pages. Individual reviewer comments for each question are identified under the heading Reviewer 1, Reviewer 2, etc. Note that reviewer comments may be ordered differently; for example, for each specific subprogram overview presentation, the reviewer identified as Reviewer 1 in the first question may not be Reviewer 1 in the second question, etc.

Presentation Number: van000
Presentation Title: Overview of VTO Analysis Program
Principal Investigator Name: Rachael Nealer (U.S. Department of Energy)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer indicated that the VAN program manages a broad portfolio of analyses, public information resources, and models that are widely used by federal and state policymakers, academics, industry, and others to assess transportation-related energy, cost, and environmental impacts. Many of these are well-established and robust models that are critical to keep current through annual updates and enhancements as new technologies enter the market. For example, the reviewer noted that it was great to see significant expansions this year into medium-duty (MD)/heavy-duty (HD) electrification in Autonomie, the Greenhouse gas Regulated Emissions, and Energy Use in Transportation (GREET) model, and VISION/NEAT. Others are newer analyses and resources that can help policymakers answer key questions, e.g., the amount of charging infrastructure the United States will need under different scenarios, and the amount a given state or local government will need (Electric Vehicle Infrastructure Projection [EVI-Pro]). Finally, pulling together key transportation data in easy digestible forms such as the Transportation Energy Data Book (TEDB) and Fact of the Week (FOTW) is an important service not just for transportation stakeholders, but the general public. The reviewer pointed out that there are many specific technical barriers associated with developing and maintaining all of these resources, but the overall portfolio seems well-designed and managed.

Reviewer 2:

The reviewer reported that objectives were clearly defined and a methodology was described, which provided a context for the various initiatives funded by VTO. The reviewer appreciated increased emphasis in areas beyond primarily passenger cars, with more tools developed and applied to MD and HD trucks. New initiatives were described in advanced transportation technologies such as connected autonomous vehicles. The reviewer noted that the principal investigator referred to future plans to expand into off-highway equipment as well.

Reviewer 3:

The reviewer remarked the various parts of the program are complementary and provide data, modeling, and analytical capabilities that can provide insight into the energy and environmental impacts of various vehicle technologies. The approach is logical and can help inform a breadth of stakeholders across industry, government, and local/regional/national planning. The reviewer remarked that the capabilities in the VTO Analysis program provides a suite of tools that can enable stakeholders to enable understanding the impact of timelines, technology targets, and consumer behaviors.

While there is an overall structure for the program that indicates very logical portfolio selection and management, the reviewer was not clear how the various project activities coordinate the key questions and areas of focus. While each is relevant on its own, mapping out the strategic direction and integrated connections could enable even greater insight. The reviewer elaborated that this was not the issue with this particular presentation, but an observation after hearing from all of the program component projects.

Reviewer 4:

The reviewer remarked that the overview of VTO Analysis projects was clear and concise. The project overviews demonstrated that the analyses address the core missions and goals of the VTO program.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that Dr. Nealer has managed a strong set of projects, each indicating good progress.

Reviewer 2:
The reviewer said that it is difficult to provide an example of improvements to an overview presentation.

Reviewer 3:
According to the reviewer, the VAN program's broad portfolio included many technical accomplishments this year, including many significant model updates, the release of new publications and tools, and reaching the 1,000th FOTW milestone. The program does a particularly good job at balancing the need to maintain longstanding models and resources with the need to develop new tools and pathways that address emerging transportation issues (e.g., autonomous vehicles, transportation as a system, and electrification beyond the light-duty [LD] sector.)

Reviewer 4:
The reviewer would like to see more emphasis into areas related to off-highway equipment. The reviewer suspected that funding limitations are slowing the pace of including these applications into the analysis portfolio. The reviewer acknowledged having seen growth in this area, however. The reviewer has also seen effective application of tools and methods toward understanding the role of MD and HD vehicles and evaluating the technology trends, and this reviewer would like to see continued growth in this area.

Question 3: Collaboration and Coordination Across Project Team

Reviewer 1:
The reviewer found that the presentation provided demonstration of excellent collaboration and coordination across the project team.

Reviewer 2:
The reviewer commented, as noted in individual project reviews, that there seems to be strong coordination across the national laboratories and with VTO, as well as significant outreach to other agencies, industry, universities, and transportation stakeholders as appropriate.

Reviewer 3:
The reviewer stated that evidence was presented throughout the session that there was collaboration and common objectives among the team.

Reviewer 4:
The reviewer commented that projects are clearly organized to create a robust portfolio. The degree of collaboration across projects is good. As an example, the reviewer cited that the Transportation Energy Data program provides a direct resource that is used by the other projects. As another, the VTO program's benefits analysis utilizes model results to conduct the technology benefits analysis. The reviewer said that the strength of the portfolio could be even more powerfully demonstrated by conducting analyses which takes advantage of many of the models to provide unique results which can provide even greater insights for critical stakeholders.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
As noted in individual project reviews, this reviewer explained that researchers have identified future work that is generally well-designed and will help to either answer key questions or enhance models.

Reviewer 2:
The reviewer observed that Dr. Nealer is obviously taking a very thoughtful approach to managing the VTO analysis portfolio. The reviewer noted that the portfolio is shifting to consider key questions about practical

future mobility trends, such as sharing, fleet management, and the evolving vehicle mix, which will critically impact fuel use and greenhouse gas (GHG) emissions.

Reviewer 3:

The reviewer would like to see more details about future funding initiatives, particularly as they relate to evaluating the maturity of new technologies and the adoption rate modelling of new technologies, particularly MD/HD on-road and off-road applications.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer stated yes; this program supports researchers and stakeholders in assessing the potential energy, cost, and environmental benefits of a wide range of vehicles, fuels, and transportation-activity scenarios. It also helps to answer key questions that can reduce barriers to the adoption of new technologies.

Reviewer 2:

The reviewer remarked the objectives were clearly defined and the funded projects demonstrated support of those objectives.

Reviewer 3:

The reviewer commented that the analysis program is critical to providing insight into the broader impact of the advanced technology portfolio of VTO and beyond. Considering the impact of technological improvements, consumer choice, policy decisions, and societal shifts is a valuable asset to the overall DOE program, and can help provide an integrated view of the overall environmental and petroleum consumption impact of the vehicle mix.

Reviewer 4:

The reviewer indicated yes; the project overview supports DOE VTO's overall objectives concerning analyses of the transportation sector's future energy and environmental issues.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer observed sufficient resources to achieve the stated milestones. However, the reviewer recommended further increases to consider the additional barriers and transportation trends that can provide even greater impact to decision makers and to VTO for portfolio guidance. The analysis program plays a critical role, not just for internal DOE portfolio management and guidance, but also provides insights to a variety of other government and industry stakeholders who use the analysis to inform their broader set of business and investment decisions.

Reviewer 2:

All projects reviewed seemed to be meeting milestones on target from this reviewer's perspective.

Reviewer 3:

The reviewer pointed out that funding levels appear to lack clarity early in the fiscal year (FY), which may have resulted in a delay in developing and articulating a robust strategy for growing the analysis plans. There is evidence that this uncertainty may have led to less aggressive movement into new applications, technology selection, and evaluation plans until late in the budget year when a more certain plan was available.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0*). In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 8-1—Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
van016	Transportation Data Program: A Multi-Laboratory Coordinated Project	Stacy Davis (ORNL)	8-6	3.75	3.88	3.75	3.25	**3.75**
van017	ANL VTO Analysis Modeling Program	Michael Wang (ANL)	8-10	3.38	3.38	3.50	3.25	**3.38**
van018	VTO Program Benefits Analysis	Tom Stephens (ANL)	8-14	3.13	3.50	3.38	3.38	**3.38**
van023	Assessing the Energy and Cost Impact of Advanced Technologies through Model-Based Design	Aymeric Rousseau (ANL)	8-18	3.50	3.38	3.38	3.38	**3.41**
van026	Modeling Framework and Results to Inform Charging Infrastructure Investments	Eric Wood (NREL)	8-22	3.75	3.75	3.63	3.50	**3.70**
van028	Electric Vehicle—Grid Benefits Analysis	Anand Gopal (LBNL)	8-26	3.38	3.38	3.25	3.25	**3.34**
Overall Average				**3.48**	**3.54**	**3.48**	**3.33**	**3.49**

Presentation Number: van016
Presentation Title: Transportation Data Program: A Multi-Laboratory Coordinated Project
Principal Investigator: Stacy Davis (Oak Ridge National Laboratory)

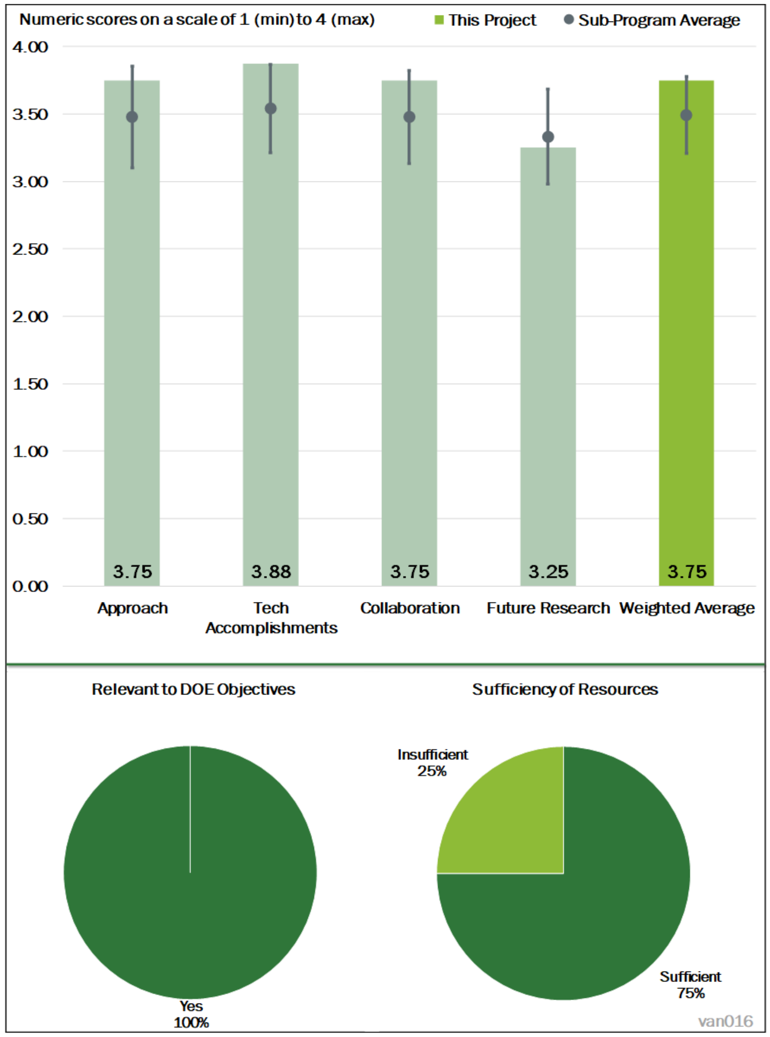

Figure 8-1 - Presentation Number: van016 Presentation Title: Transportation Data Program: A Multi-Laboratory Coordinated Project Principal Investigator: Stacy Davis (Oak Ridge National Laboratory)

Presenter

Stacy Davis, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the TEDB is an important resource to many transportation stakeholders, including other federal agencies, academics, and industry representatives. As noted by the presenter, compiling the many sources of data into one well-documented resource is an efficient way to save researcher's and stakeholder's time. The reviewer noted that the time series data is particularly helpful. One of the biggest technical challenges is presenting time series data for cases where changes in definitions or methodology of the underlying data sets cause a break in the time series. The reviewer remarked Oak Ridge National Laboratory (ORNL) addresses this by noting any such breaks and providing as much detail as possible on the changes that occurred—a reasonable approach. Likewise, FOTW and e-drive sales data is well-presented, documented, and useful to an array of stakeholders. The reviewer found that all projects seem well-designed and are clearly feasible.

Reviewer 2:

The reviewer said the project had clearly laid-out objectives and methodology. The reviewer noted how the authors expressed a commitment to providing information, data, and reports to meet the needs of the user community.

Reviewer 3:

The reviewer remarked that Ms. Davis and team provide a very thorough and methodological approach to the transportation data program. The team is very seasoned, and clearly knows the material and how to synthesize the information in a very logical and well-documented manner.

Reviewer 4:

The reviewer commented that the data system is getting better with more access options. The data system is well-defined and feasibility is not an issue.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer reported that all milestones for FY 2017 are complete and are either complete or on track for FY 2018. This includes posting monthly e-drive sales data, preparing and posting the FOTW, and submitting the draft TEDB to the VTO.

Reviewer 2:

The reviewer has seen an increased emphasis toward moving into new transportation technologies for passenger cars and LD vehicles, but also including fleets, HD vehicles, non-highway sectors, and other relevant energy and alternative fuel technologies.

Reviewer 3:

The reviewer remarked that the team is making very solid progress towards the overall project. The team consistently delivers and actively engages partners to make the data as useful and accessible as possible.

Reviewer 4:

The reviewer referenced a prior comment; the data system is invaluable to analysts and exceeds technical accomplishments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that Ms. Davis and team seek out collaboration and coordination across the project team and across the VTO analysis portfolio. The team positions the TEDB as a community resource and seeks to serve the community as effectively as possible.

Reviewer 2:

The reviewer found that collaboration between ORNL and Argonne National Laboratory (ANL) partners, as well as with VTO staff, seems well-coordinated. In addition, the project partners work with many outside groups, agencies, etc., on the data sources used in the Transportation Data Program and do a good job on stakeholder outreach (e.g., through email subscriptions).

Reviewer 3:

The reviewer said that the presenter expressed a keen interest in collaborating and providing creative ways to address the needs of the user community.

Reviewer 4:

The reviewer asserted that no comment is needed; the system is improving due to coordination and collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer commented that future work for this program entails continuing to publish e-drive sales data, FOTW, and the TEDB on a regular basis. Now that the TEDB is an online-only resource, it will be updated twice per year—a good enhancement. The reviewer recommended that if possible, it could be useful to stakeholders to have e-drive sales data broken out by state (or U.S. region) in order to explore the impacts of state or regional policies and programs on plug-in electric vehicle (PEV) adoption. The reviewer explained that if this is not possible because the underlying data are proprietary, any aggregate version of this data (e.g., total electric vehicle [EV] sales for state x, rather than sales by manufacturer or model) could still be useful.

Reviewer 2:

The reviewer described the Transportation Energy Data program as a very consistent resource that could become even more valuable by seeking new sources and information that can provide an even broader resource with future shifts in mobility patterns and transportation use. For example, the reviewer suggested that information related to ride share use and the link between private and public transportation could provide additional insight and expand the project's stakeholder community.

Reviewer 3:

The reviewer reported evidence of growing research to include more off-highway data needs and expressed interest in seeing an increased effort applied in this area, particularly around technology trends.

Reviewer 4:

The reviewer said that a comment is not applicable for development of a well-regarded and used data system.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer pointed out that providing timely, well-documented, and high-quality data enables researchers and other transportation stakeholders to advance studies and projects that could make passenger travel and freight movement more energy efficient and cost-effective.

Reviewer 2:

The reviewer said that the Transportation Energy Data project continues to provide a reliable and consistent resource for DOE and the community of users. Through the Data Book and FOTW, it provides a synthesis, distribution, and educational service on transportation energy use and trends that benefit stakeholders across government, academia, and the private sector.

Reviewer 3:

The reviewer asserted that the data system is a very important tool for VTO analyses.

Reviewer 4:

The reviewer observed excellent data resources for the bulk of the market trends, particularly in LD and passenger cars; however, less so in MD and HD transportation and off-highway sectors.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked that resources appear to be insufficient to comprehensively cover all three sectors, specifically LD passenger cars, commercial vehicles, and off-highway equipment.

Reviewer 2:

The reviewer explained that funding seems well-utilized and project partners have been able to meet all targets and milestones with the resources provided.

Reviewer 3:

The reviewer commented that the team does an admirable job of using resources appropriately to deliver weekly, monthly, and annual milestones.

Reviewer 4:

The reviewer indicated that resources seem sufficient.

Presentation Number: van017
Presentation Title: ANL VTO Analysis Modeling Program
Principal Investigator: Michael Wang (Argonne National Laboratory)

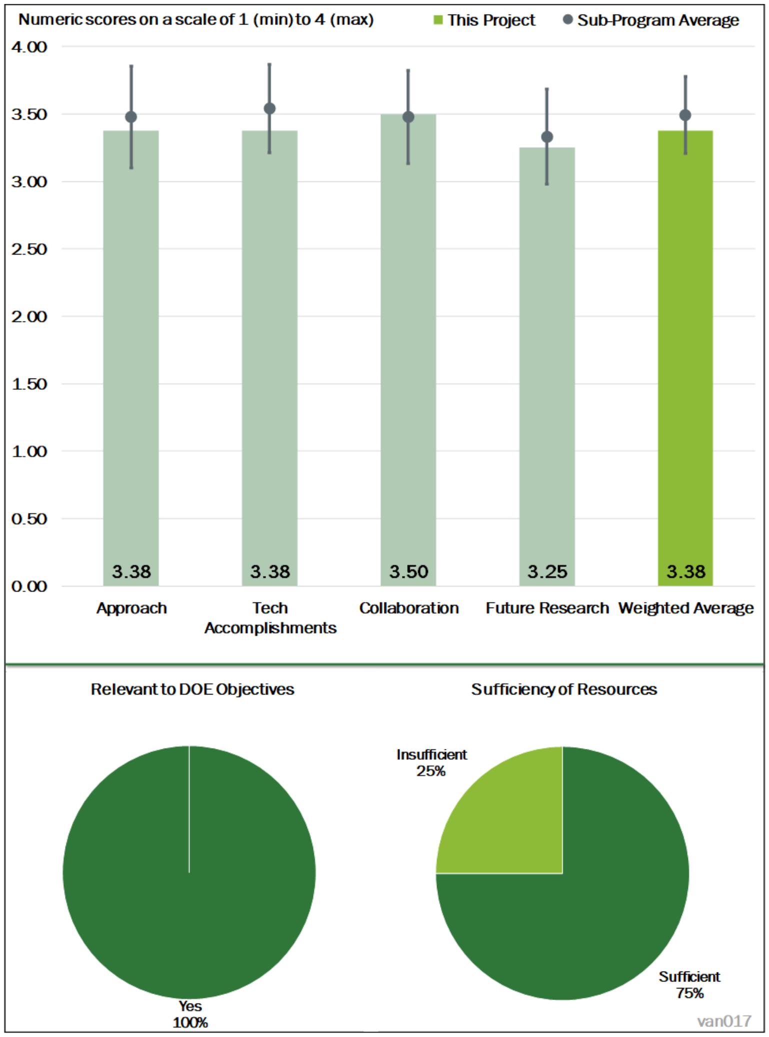

Figure 8-2 - Presentation Number: van017 Presentation Title: ANL VTO Analysis Modeling Program Principal Investigator: Michael Wang (Argonne National Laboratory)

Presenter

Michael Wang, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer asserted that models are an excellent resource to researchers and transportation stakeholders trying to assess the energy and environmental impacts of different vehicle and fuel pathways, as well as fleet deployment scenarios. While there are many technical challenges associated with developing and updating such extensive models, ANL works with partners to gather and vet data and try to address inconsistencies. The reviewer said that ANL consistently documents any updates to the models, including new pathways, changes to underlying data sources, and methodology.

Reviewer 2:

The reviewer observed a solid approach that has been developed over many years of research. The capabilities have expanded over time to provide a well-known and used resource for the community for calculating GHG emissions.

Reviewer 3:

The reviewer remarked that the approach provides comprehensive coverage for the GREET and VISION/NEAT models for on-highway vehicles. The reviewer cited how the project team has increased emphasis in the past year on MD and HD vehicle technologies in the EV, plug-in hybrid electric vehicle (PHEV), and fuel cell electric vehicle (FCEV) technology areas. The reviewer would like to see continued growth in this direction as well as including off-highway sectors in these technology areas, particularly construction, industrial, and agricultural sectors.

Reviewer 4:

The reviewer remarked that the GREET and VISION tools are a good basis for evaluating the life cycle analysis (LCA) of emissions and energy consumption under different assumptions and scenarios. The reviewer agreed with last year's commenter that system boundaries could use further development. In particular, the temporal boundaries for some energy system change, i.e., crude oil production; emission and energy use for certain reservoir types change over the life of the well or reservoir. The reviewer thought it would be helpful if GREET addressed this issue in the future.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that ANL made many significant updates to the models in the past year, in particular, the regional water analysis in GREET and incorporating EV/FCEV pathways beyond the LD sector in VISION and NEAT. The reviewer noted that milestones appear on time.

Reviewer 2:

The reviewer observed excellent progress toward stated goals.

Reviewer 3:

The reviewer acknowledged that the project continues to make progress year over year. However, the presentation and materials focused much more on the approach rather than articulating the progress, impact, and priorities for expanding the model. The reviewer said that it would be good to clarify up front what the priorities are for additional development and the desired set of results, and stakeholders who would be impacted by the additional development for the year.

Reviewer 4:

The reviewer found that the technical accomplishments and progress of GREET and VISION is excellent. However, the reviewer reiterated a previous comment on progress on the temporal boundaries of GREET.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that ANL seems to do an outstanding job of collaboration both within DOE and with external stakeholders spanning industry, the U.S. Environmental Protection Agency, the U.S. Department of Transportation (DOT), and research organizations. This is a critical component of the modeling work given the large number of inputs, assumptions, and external models that inform GREET and VISION/NEAT.

Reviewer 2:

The reviewer commented GREET and VISION model development collaboration and coordination.

Reviewer 3:

The reviewer remarked that collaboration and coordination appear to be strong with other stakeholders at the federal and national laboratory levels. The reviewer suggested that perhaps increasing interaction with industry stakeholders would add some outside, market-driven influence into the areas of growth for future technologies and additional market sectors. The reviewer appreciated the proposed future work toward developing a simplified online version of VISION/NEAT. This could encourage industry use of these valuable tools.

Reviewer 4:

The reviewer commented that the project continues to work consistently with partners and continued users of GREET. However, it is unclear whether there were a key set of questions or issues driving the additional development. The project updated results based on the Annual Energy Outlook 2017 reference cases and included MD and HD vehicles, but it was unclear how or whether this linked to the activities in the water stress index work. The reviewer said that clarity on the priorities for model expansion would be helpful in articulating decisions for model expansion and subsequent analyses.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer detailed that ANL's future plans for GREET include adding new vehicle technologies and pathways such as plug-in MD/HD vehicles and autonomous vehicles. The reviewer remarked that these are timely additions will enhance the usefulness of the model for stakeholders trying to understand the energy and environmental impacts of new technologies that are just starting to enter the market. The reviewer noted how identifying default input assumptions for such new technologies are a challenge across the modeling and transportation communities. However, ANL's approach of gathering information from a wide variety of stakeholders, clearly documenting sources, allowing model users to easily change input assumptions, and regularly updating assumptions helps mitigate this risk. The reviewer noted that work to address LCA regional boundary issues, vehicle lightweighting, and continued improvement on assumptions for water consumption will also enhance the model. The reviewer suggested that ANL might consider expanding the well-to-wheels calculator to include additional pathways (e.g., MD/HD vehicles) in future years.

Reviewer 2:

The reviewer recommended that additional areas for consideration are off-highway sectors, particularly construction, industrial, agricultural, and marine equipment and relevant technologies. The reviewer noted that these possess a similar technology suite to MD/HD on-highway commercial vehicles, but applications and duty cycles as well as economic assumptions influencing technology trends will vary for these industry sectors. The reviewer suggested that the project team's considerations should include alternative fuels, connected and autonomous vehicles, EVs, FCEVs, PHEVs, hybrid electric vehicle (HEV) technologies, and other emerging technologies.

Reviewer 3:

Regarding the future work capabilities list, the reviewer suggested it would be good to include context on including these capabilities for the drivers (e.g., additional questions that will be addressed, key stakeholders driving the prioritization, and what the desired outcome will be). The reviewer pointed out that the GREET model can be expanded in many directions, and so understanding how to have the biggest impact with the given resources should drive prioritization.

Reviewer 4:

The reviewer found that proposed future work for GREET and VISION is effective, but could be better if GREET addressed the boundary condition issues mentioned in prior comments.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer noted that GREET provides a well-documented and accepted methodology for calculating well-to-wheels emissions for a variety of vehicles and fuels. According to the reviewer, having such a tool accessible to the broad transportation community clearly supports the overall DOE objectives of reducing emissions by providing a tool to calculate emissions.

Reviewer 2:

The reviewer stated yes; these models help researchers and stakeholders analyze the energy and environmental impacts of a wide range of vehicle and fuel pathways. As such, they can help assess the potential energy benefits of programs and policies to advance energy goals.

Reviewer 3:
The reviewer said there is no question that the GREET and VISION tool development is highly relevant for DOE and VTO program and mission.

Reviewer 4:
The reviewer had no additional comments.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer explained that resources appear sufficient to manage the current breadth of applications and technologies, but may lack sufficient resources to expand beyond the current scope into the suggested areas included in prior response.

Reviewer 2:
The reviewer commented that resources seem sufficient, project milestones have been met or are on target, and future work seems well-planned.

Reviewer 3:
The reviewer remarked that resources seem sufficient, however, and the team needs to more clearly articulate priorities for the project’s next steps.

Reviewer 4:
The reviewer noted that resources seem sufficient.

Presentation Number: van018
Presentation Title: VTO Program Benefits Analysis
Principal Investigator: Tom Stephens (Argonne National Laboratory)

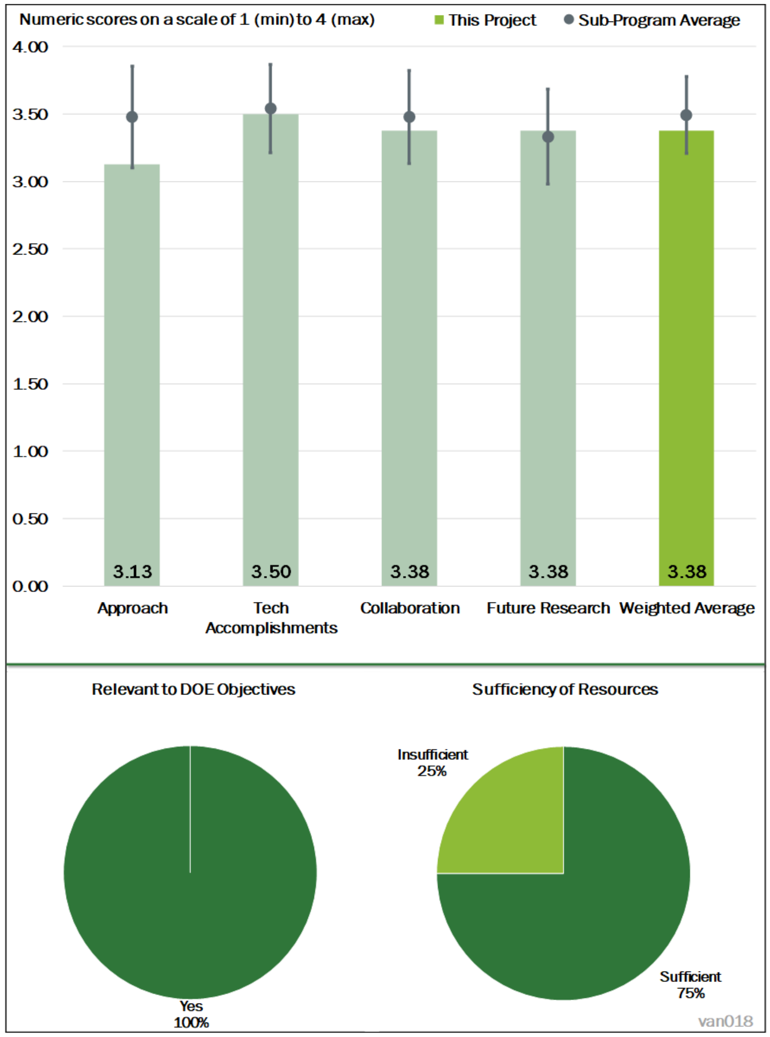

Figure 8-3 - Presentation Number: van018 Presentation Title: VTO Program Benefits Analysis Principal Investigator: Tom Stephens (Argonne National Laboratory)

Presenter

Tom Stephens, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the team uses the VTO-developed models to conduct their analyses. The approach is reasonable, and the team utilizes multiple approaches and compares results to better understand what factors will impact the desired outcomes of petroleum use and GHG emissions.

Reviewer 2:

The reviewer described that the objective of this analysis—assessing the benefits of VTO program targets—is interesting and potentially useful for VTO in making future program decisions. The researcher has established a reasonable modeling framework to approach the question. However, there are many technical challenges associated with drawing boundaries for, and attributing benefits to, the different technologies being assessed as well as in determining how sensitive results are to different assumptions (e.g., fuel prices).

The reviewer noted that the researcher has conducted some initial tests addressing some of these challenges; e.g., varying the order that different technologies are applied. The reviewer strongly recommended additional sensitivities and side cases. In particular, it would be useful to look at program success scenarios one at a time for individual technology/subprogram targets, i.e. how big are potential program benefits if fuel cell targets are reached but battery electrification and other program targets are not achieved (base case) and vice versa. The proposal to explore sensitivity to fuel costs also seems critical as this may be a significant driver of vehicle choice models and would likely not impact subprogram areas equally.

Reviewer 3:

The reviewer said the project team has demonstrated that additional applications and technologies have been taken into consideration, particularly in the areas of MD and HD trucks. The reviewer expected to see continued future growth in this area, but appreciated that there has been a growing level of commitment this past year.

Reviewer 4:

The reviewer commented the issue with the approach is that the analysis results are from assumptions that may not play out in the real world. If that is stated upfront, there should not be a problem if everyone understands the initial set assumption. The reviewer acknowledged not having a suggestion to overcome this, except to reiterate that the results are not predictors but possible outcomes that do not assign a level of uncertainty.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer indicated that project milestones seem complete or on track.

Reviewer 2:

The reviewer asserted that the project is effective at overcoming most barriers. There is a good recognition of the importance of all on-highway sectors, specifically, LD, MD, and HD vehicles.

Reviewer 3:

The reviewer remarked that accomplishments and progress in the presentation indicate that the project is well-managed and strives to reach the intended outcome.

Reviewer 4:

The reviewer commented that the team conducted a methodological assessment of the technology components of the DOE program and their potential impact on fuel consumption. The analysis provides insight into the factors that contribute to reductions in petroleum use over time. Moreover, the reviewer highlighted that the team also shows initial results indicating that lower fuel costs may offset the additional cost of the vehicle improvements. This type of analysis can provide broader context to help inform decision makers.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that the project seems well coordinated with VTO, the national laboratories, and other project partners, which is critical given that the analysis uses multiple models (and model types) to assess program benefits.

Reviewer 2:

The reviewer noted how this project uses models across the VTO analysis portfolio to examine the impact of the VTO program advanced technology R&D. The team collaborates closely with the other performers and clearly indicated how each of the collaborators is engaged.

Reviewer 3:

The reviewer reported that collaboration and coordination presented appear to be more than adequate.

Reviewer 4:

The reviewer said that collaboration and coordination among federal and national laboratory stakeholders and supporting organizations seems to be good. The reviewer suggested more industry outreach to involve more stakeholders to influence future direction.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer described how proposed future work includes analyzing sensitivities and uncertainties associated with inputs/assumptions, and conducting additional scenarios/cases to look at the influence of meeting subprogram targets individually. As noted earlier, this seems critical to assessing (and properly attributing) the benefits of meeting technology targets in different areas. The reviewer is glad to see this in future plans.

Reviewer 2:
The reviewer remarked that proposed future work is reasonable. In particular, the ability to consider sensitivities and consider hundreds of combinations would be useful for understanding the range of impact each factor may have. The reviewer said that the team should also consider including the impact of other advances in both technology and future vehicle utilization models to identify whether additional synergies may exist within the program investments.

Reviewer 3:
The reviewer detailed how plans include increased analysis of VTO technologies in MD and HD vehicles, including more effort in this calendar year. The reviewer would like to see continued growth in this sector, and suggested including industry's view toward off-highway applications as well, including construction, industrial, agriculture, and marine applications. The reviewer pointed out that there is some overlap of relevant technologies in the commercial vehicle sector that is relevant for study here.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:
The reviewer said yes, assessing the benefits of VTO technical targets (if done with sufficient rigor) can directly inform DOE's programmatic decisions in order to help maximize potential energy, cost, and environmental benefits.

Reviewer 2:
The reviewer pointed out that the project supports overall DOE objectives by providing a venue for identifying the potential impact of advanced DOE technologies. It provides a venue for scenario analyses and considers a mix of technological impacts on emissions' given costs.

Reviewer 3:
The reviewer indicated that this work must be performed to support DOE senior management decisions.

Reviewer 4:
No further comments were offered by this reviewer.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer advised that resources may be insufficient to grow into the additional market sectors and relevant technologies stated in previous comments.

Reviewer 2:
The reviewer said that resources seem sufficient given that milestones have been met or are on target.

Reviewer 3:

The reviewer commented that resources seem sufficient to keep the team on track for milestones.

Presentation Number: van023
Presentation Title: Assessing the Energy and Cost Impact of Advanced Technologies through Model-Based Design
Principal Investigator: Aymeric Rousseau (Argonne National Laboratory)

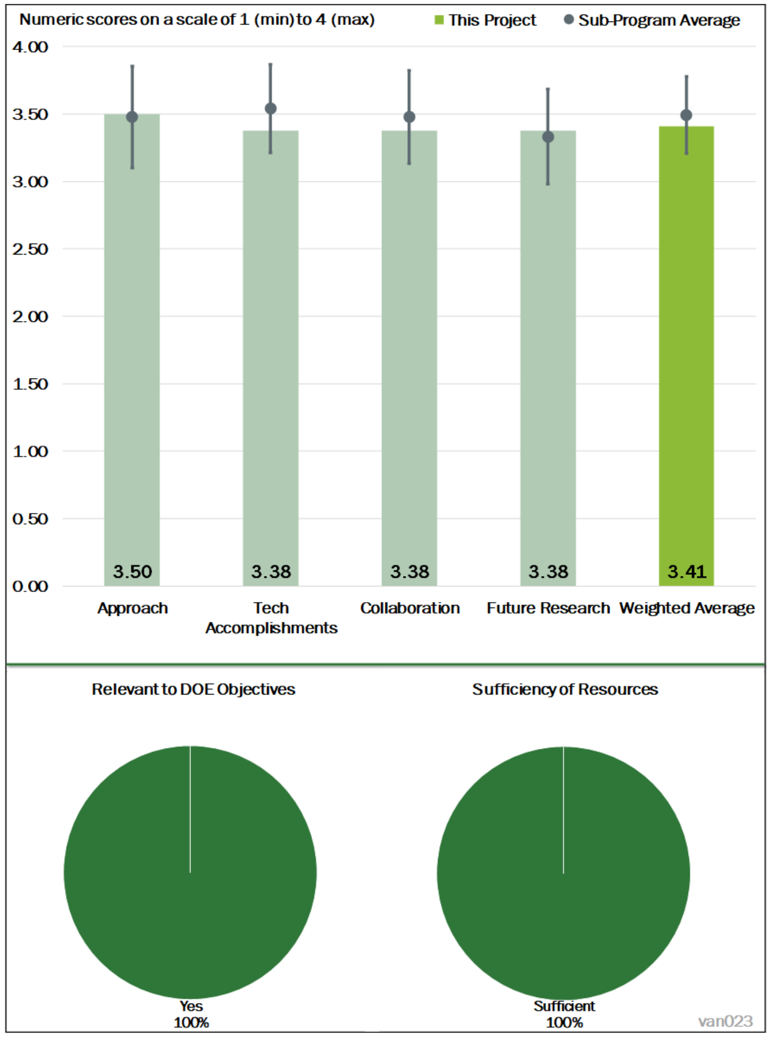

Figure 8-4 - Presentation Number: van023 Presentation Title: Assessing the Energy and Cost Impact of Advanced Technologies through Model-Based Design Principal Investigator: Aymeric Rousseau (Argonne National Laboratory)

Presenter

Aymeric Rousseau, Argonne National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer reported that the presentation clearly explained the approach. The team has transitioned from LD into MD/HD on-highway applications and defined 15 target application/vehicle types.

Reviewer 2:

The reviewer pointed out that ANL is expanding Autonomie to include additional vehicle classes, vocations, and powertrain combinations, increasing its utility to analysts and members of the transportation community. There are significant technical barriers associated with identifying vehicle specifications and inputs, particularly for new technologies that are less well-established in the market, such as MD/HD electric and fuel cell vehicles. The reviewer pointed out that ANL addressed these barriers by conducting its own analyses of the power levels /battery sizing and other specifications that would be needed to match the performance of a baseline vehicle (e.g., using FleetDNA). The reviewer remarked that this seems like a reasonable approach for establishing an initial modeling framework for new technologies. The reviewer noted that future plans to formally gather feedback from original equipment manufacturers (OEMs) on MD/HD electrification and other new technologies as the market evolves will further enhance the model.

Reviewer 3:

The reviewer noted that the majority of the effort has been focusing on building up the capability to include MD and HD vehicles. The approach seems sound, building upon work from other agencies and extending the LD model to account for MD and HD vehicles with various powertrains. The reviewer noted that significant attention has been on gathering appropriate input parameters from DOT and DOE, including previous studies and roadmaps. Moreover, according to the reviewer, the team has engaged relevant stakeholders, which is critical given the diversity of MD & HD vehicles and for creating foundational models that can support a broad community.

Reviewer 4:

The reviewer commented that the Autonomie model is extremely data, and assumption intensive, and recommended that the model be benchmarked and/or compared to lumped parameter models and empirical data. The results and costs of development of the two modeling approaches should be evaluated and compared on an ongoing basis.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the technical accomplishments and progress presented indicate that the project is well-managed to achieve the goals of the VTO analyses program.

Reviewer 2:

The reviewer reported that the LD report is complete, and MD and HD work seems to be on target. The reviewer pointed out that initial assumptions for new MD and HD combinations are complete.

Reviewer 3:

The reviewer pointed out that a comment made on Slide 3 that the "benefits of vehicle technology improvements for the [MD and HD] vehicles are not well understood." This is not a criticism, but perhaps an acknowledgement that the transition from studying LD vehicles into the MD and HD sector has just begun within the past 8 months. The reviewer remarked this is a welcome transition. The opportunities seem to be significant in effectively deploying technologies into this sector. The reviewer speculated that perhaps more study is needed to understand the potential value that can be achieved in this sector. Similarly, the same question can be asked of the off-highway sectors, although the chart on Slide 3 suggests diminishing returns from marine, rail, and other. The reviewer wondered if perhaps further study is necessary to understand the implications in these sectors.

Reviewer 4:

The reviewer said the team has incorporated input data and verified the model results against other established reports and studies. The team has been explicit about assumptions and scope, and has been guided by OEM, DOT, DOE, and other partner input. The reviewer suggested it would be good for future reviews to be more explicit about how stakeholders are using the results, whether and how many requests for analyses the team has received and executed, and what outcomes resulted from those analyses and queries.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the project team is collaborating and receiving input from a number of stakeholders and partners across DOE, DOT, and OEMs, which is guiding the model development appropriately.

Reviewer 2:

The reviewer remarked that the collaboration and coordination across multiple internal and external model uses is excellent. The reviewer did not have any suggestions for improvement except for maintaining collaboration and coordination efforts.

Reviewer 3:

The reviewer stated yes, ANL is coordinating with VTO and the Fuel Cell Technologies Office as well as with other national laboratories, agencies, OEMs, suppliers, universities, and other organizations on modeling inputs and assumptions.

Reviewer 4:

The reviewer said that collaboration is good as currently defined. The reviewer suggested more industry collaboration to help identify questions relevant to industry that modeling by ANL can support, and to give industry the opportunity for greater input into the direction that future work may take in evaluating both on-highway and off-highway technology applications.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer noted how ANL has identified multiple ways to continue to enhance the Autonomie model (e.g., adding additional powertrains and vehicle classes, cost estimation) as well as to make current inputs more robust. Given the technical challenges associated with developing assumptions for MD/HD electrification, this reviewer commented that ANL's plans to more formally gather feedback from OEMs on these assumptions may be particularly useful, and likewise for the proposal to develop a vehicle technology database.

Reviewer 2:

The reviewer found that the proposed future work is appropriate. It would be further strengthened by identifying key questions and issues of interest to the stakeholder community and clarifying how those questions are guiding model development and publishing the resulting analyses.

Reviewer 3:

The reviewer requested more information into how Autonomie has been used by the MD/HD vehicle OEMs, and to explore how to further exploit these capabilities in the future. The reviewer would suggest a similar extension to the off-highway sectors of construction, industrial, agriculture, forestry, and marine as the on-highway work transitions into next steps and into the off-highway sector.

Reviewer 4:

The reviewer referenced prior comments made in question 2, about comparing results with empirical data and other simpler models.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer said yes, the Autonomie model can help researchers and stakeholders analyze the energy and cost impacts of advanced technologies, which are important to assessing the potential energy benefits of transportation policies and programs.

Reviewer 2:

The reviewer stated the project supports overall DOE objectives by providing an energy and cost assessment model for examining the impact of light, MD, and HD vehicles with a variety of system components and alternative powertrains.

Reviewer 3:

The reviewer commented that the project supports the VTO mission because it is important to have analyses result from this project that can help direct and evaluate R&D future benefits and costs.

Reviewer 4:
The reviewer had no further comments.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:
The reviewer explained that a more clearly defined approach to other sectors, such as off-highway, can identify if resources are sufficient to study MD/HD on-highway and the off-highway applications, with its higher degree of application and equipment proliferation.

Reviewer 2:
The reviewer said that resources seem sufficient to achieve the stated milestones.

Reviewer 3:
Resources seemed sufficient to this reviewer. Project milestones have been met or are on target, and future work seems well-planned. The reviewer was unclear to what extent additional funding would be needed for future work.

Reviewer 4:
This was a difficult question for this reviewer to answer. The reviewer asked whether project costs justify the results, or whether there is another modeling technique and other data to gather that can provide comparable results with less resources. This reviewer also referenced prior comments.

Presentation Number: van026
Presentation Title: Modeling Framework and Results to Inform Charging Infrastructure Investments
Principal Investigator: Eric Wood (National Renewable Energy Laboratory)

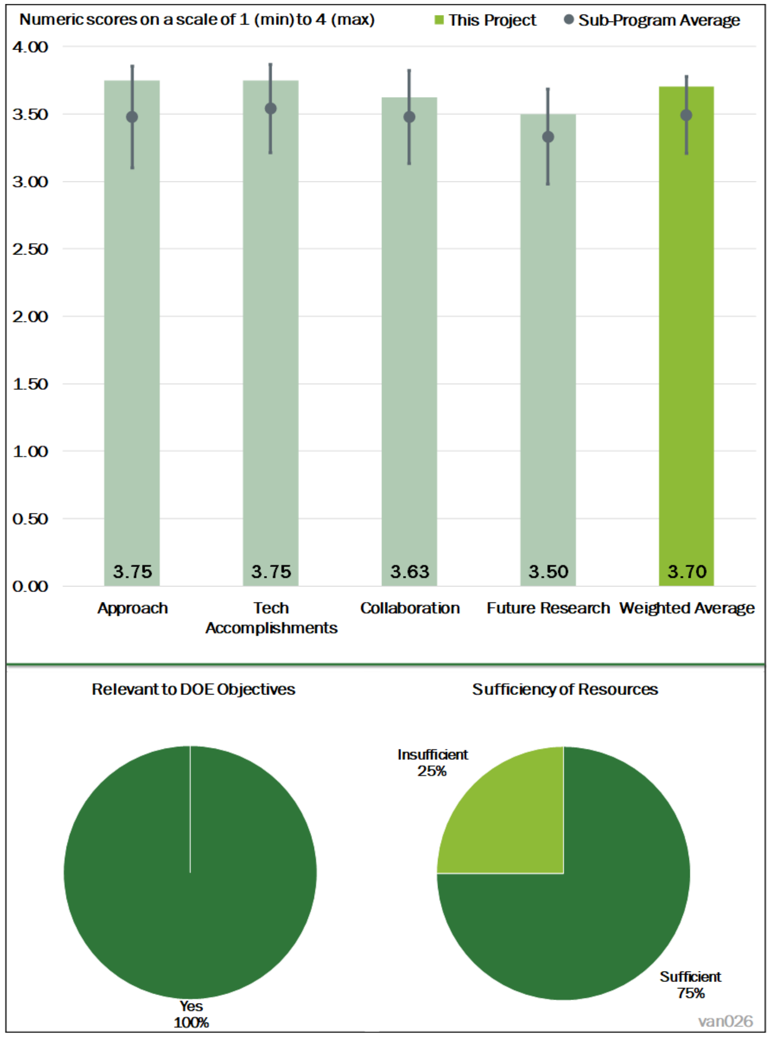

Figure 8-5 - Presentation Number: van026 Presentation Title: Modeling Framework and Results to Inform Charging Infrastructure Investments Principal Investigator: Eric Wood (National Renewable Energy Laboratory)

Presenter

Eric Wood, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the modeling framework and analyses presented can help significantly inform U.S. public charging infrastructure needs at both the national and state/local levels, and thus help to reduce a key barrier to PEV adoption. Modeling potential load profiles of direct-current (DC) fast charging, and analyzing the effectiveness of different strategies (e.g., onsite storage, renewable generation) to reduce demand charges can likewise help to reduce barriers to consumer adoption of these new technologies.

The reviewer described the five completed projects as well-defined and feasible. There are many uncertainties associated with estimating future infrastructure needs such as technology developments and consumer preferences. The reviewer pointed out that the National Renewable Energy Laboratory (NREL) addressed this technical barrier by using sensitivity analyses to test the impact of different variables and input assumptions. While shared mobility (or other factors that could significantly shift how vehicles are used and how much infrastructure is needed) was outside the scope of this modeling framework, the researchers are considering this in future work. The reviewer remarked that from the information presented, plans for the multi-unit dwelling (MUD) charging work also seem well-designed and feasible.

Reviewer 2:

The reviewer observed a good approach to developing a better understanding of the issues and factors of electric vehicle supply equipment (EVSE). The reviewer pointed out this is necessary work to provide a foundation for developing future strategies around charging infrastructure.

Reviewer 3:

The reviewer remarked the project team has done an excellent job of looking at a variety of geographies, approaches, and issues associated with creating charging infrastructure EVs. The project team is combining local, regional, and national consumer travel data, utility cost models, and other existing reports and models for EV charging requirements as inputs for their modeling and analyses. The reviewer said the team is also making the tools available online to enable a broad community of stakeholders to access the capabilities. This will enable greater impact and leverage the investments.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer pointed out that the team has completed five of the six analyses, with several publications and the EVI-Pro Lite tool released for public use. Other project papers and work seem on target. The reviewer noted that the team has done extensive technical work to date to establish, test, and perform sensitivity analyses on modeling framework and results. The work was appropriately informed by national and local travel data, an examination of utility rate structures, and stakeholder and expert input.

Reviewer 2:

The reviewer said the project provides a good foundation of evaluation and case studies, and it is also helpful to define future challenges and the need for information around the uncertainties of PEVs, MUDs, transportation network company (TNCs), etc. The reviewer remarked that it seems like more study is needed to understand these uncertainties.

Reviewer 3:

The reviewer stated that the team has produced an impressive set of capabilities and results that have been well-documented and shared with a variety of stakeholders. The reviewer pointed out that, based on previous reviewer comments, the team has also focused efforts to include large PEV market areas, and explicitly focused on broad stakeholder engagement, which will further amplify and extend the impact of the tools and results.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer observed project partners coordinated across national laboratories, and with state and local governments, federal agencies, universities, EVSE providers, utilities, automakers, and other stakeholders.

Reviewer 2:

The reviewer noted good collaboration with government and industry in the target sectors. The reviewer suggested more representation from the commercial vehicle sector would be useful, particularly the area of LD and MD urban commercial vehicles.

Reviewer 3:

The reviewer remarked the team has conducted workshops and targeted engagements with relevant stakeholder communities for PEV charging infrastructure. This not only improved collaboration and coordination across the project team, but also engaged a broad set of stakeholders who can benefit from the project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:

The reviewer remarked that the proposed future work is sound and looks to gain greater insight into the future use of EVs and infrastructure needs given the shifts in consumer and public needs. The reviewer pointed out that charging at MUDs will be significant with increasing urbanization, and ride-hailing and car-sharing will create additional shifts in the way consumers utilize transportation—with potentially significant impact on EV adoption and ownership models. The reviewer noted that these are critical issues for the DOE to consider. This proposed work is well-aligned with addressing barriers to EV adoption.

Reviewer 2:

The reviewer detailed that proposed future work on charging access for MUD residents, electrification of TNCs, and market uncertainty will help address key questions about future infrastructure needs. The reviewer pointed out that plans to enhance and utilize existing models (e.g., ADOPT, EVI-Pro, and Behavior, Energy, Autonomy, and Mobility [BEAM]) for these efforts in coordination with partners increases the likelihood of success.

Reviewer 3:

The reviewer said that there are clearly many issues that need a better understanding in the LD vehicle sector, particularly how urban mobility will change in the foreseeable future, and the implications for EVs. The reviewer noted it is important to understand the various plausible scenarios for LD vehicles first, but perhaps it is not too soon to begin discussing LD commercial vehicles and the implication for other commercial vehicle types.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer stated yes; these projects help remove barriers to the adoption of advanced technology vehicles.

Reviewer 2:

The reviewer found that this project is well-aligned with DOE objectives for reducing petroleum consumption and GHG emissions. This project is particularly well-positioned to have impact across a variety of stakeholders at DOE, other federal agencies, and the broader transportation stakeholder community.

Reviewer 3:

The reviewer had no further comments.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer commented that the resource profile for FY 2018 seems low to continue progress and achieve goals. FY 2019 funding was not shared in the review materials. There is a tremendous set of output from the project given the resources, and the reviewer suggested increasing support to further accelerate progress and dissemination of the model and results.

Reviewer 2:

The reviewer noted that resources seem sufficient for current work, and project milestones have either been met or are on target. The reviewer was not clear if proposed future work would need additional resources.

Reviewer 3:

The reviewer remarked that the questions needing answers are broad, and collaboration with others who are also studying these questions is essential. The reviewer thought the project approach and collaborators listed suggest that collaboration is good and leveraging these resources should be a focus for future work.

Presentation Number: van028
Presentation Title: Electric Vehicle—Grid Benefits Analysis
Principal Investigator: Anand Gopal (Lawrence Berkeley National Laboratory)

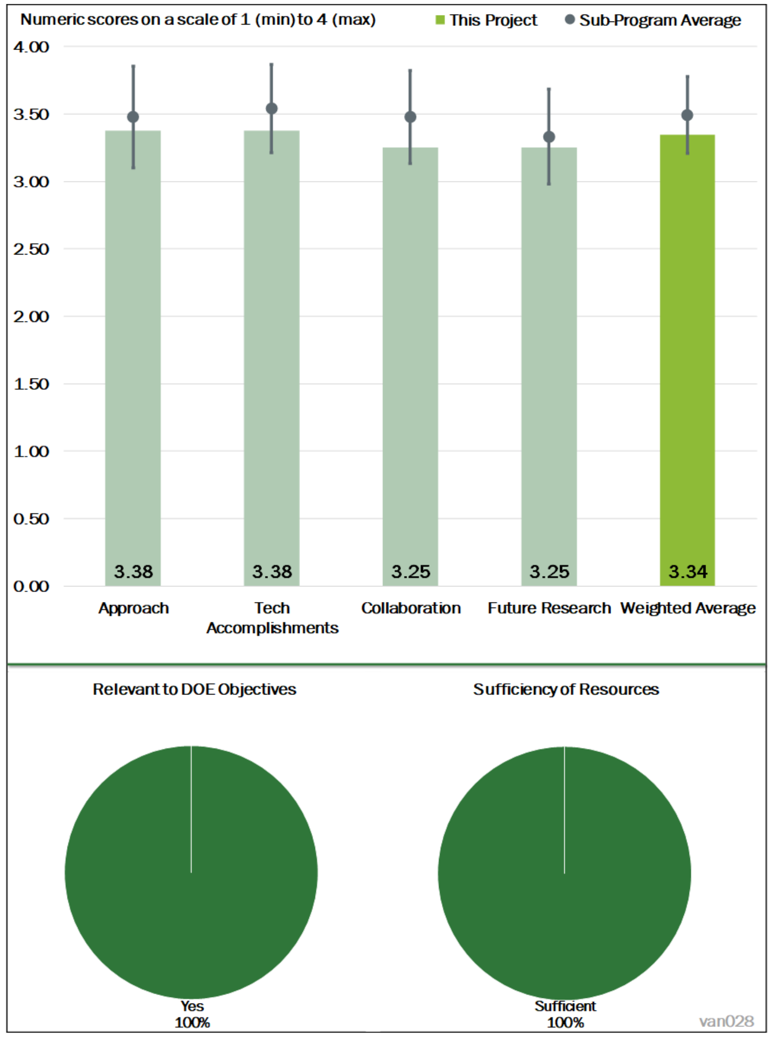

Figure 8-6 - Presentation Number: van028 Presentation Title: Electric Vehicle—Grid Benefits Analysis Principal Investigator: Anand Gopal (Lawrence Berkeley National Laboratory

Presenter

Anand Gopal, Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer reported that the team links mobility and grid models to estimate costs and benefits of integrating millions of PEVs onto the grid. The team used the accepted BEAM charging model and PLEXOS power sector model to conduct the analyses to look at integration in California, and then extend the results nationally for various charging schemes. The reviewer found that the approach is sound and addresses important the important barrier of PEV charging on the grid.

Reviewer 2:

The reviewer described the approach as clearly defined and appropriate.

Reviewer 3:

The reviewer said that this research addresses interesting questions on how EVs could impact the grid under different charging scenarios (unmanaged, smart, and time of use [TOU] charging). The researchers seem to have developed a reasonable initial framework for approaching these questions and found some interesting preliminary results. However, the reviewer observed many technical challenges, particularly in scaling the very detailed California analysis to a national one, and pointed out that there is detail lacking in the presentation to evaluate plans for that analysis.

The reviewer cited that some factors researchers might consider in scaling to the national level are whether PEV energy consumption will be significantly different in colder regions of the country due to cold weather effects on the batteries, and how TOU rate structures might vary (i.e., is the time at which lower rates kick in the same everywhere). The reviewer noted that researchers might also consider doing a few additional, detailed local analyses (similar to the one conducted for the San Francisco Bay area) in different parts of the country to help inform the national analysis. The reviewer suggested seeing the question on future work for additional sensitives that might be useful.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:
The reviewer pointed out that project milestones seem to be met or on target.

Reviewer 2:
The reviewer commented progress to-date is satisfactory based on the October 2017 project start.

Reviewer 3:
The reviewer remarked the team has made solid progress on examining managed charging strategies in California and the impact on the electric grid for a variety of adoption levels taken from the California Energy Commission forecasts. Results include the impact on renewable curtailment and the benefit of various charging schemes on more effectively utilizing renewables. The reviewer noted that results provide relevant new insights into the potential impact of managed charging strategies to better utilize renewables.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer acknowledged that some key uncertainties have been identified. The reviewer recommended that it would be helpful to add collaborators from industry to help explore some of these uncertainties and alternative approaches to the issues of grid impact, consumer reluctance to purchase new technologies, and other technology alternatives and grid options. As an example, this reviewer asked how micro-grids and distributed power can help address some of the current grid infrastructure limitations or challenges, and how renewables and energy storage enable some of these solutions.

Reviewer 2:
The reviewer noted that researchers are coordinating with ANL and a university team. For future work, the reviewer suggested the team might consider additional coordination or outreach to NREL (i.e., the team that conducted the national PEV charging infrastructure analysis) and Idaho National Laboratory (for work on charging profiles).

Reviewer 3:
The reviewer said the project is well-coordinated with government and university partners in California. The reviewer explained that input from national stakeholders and increased interaction with the other VTO analysis performers should enable the project to have even more impact as well as benefit other projects within the portfolio.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways.

Reviewer 1:
The reviewer topics for consideration as future work, including how micro-grids and distributed power can help address some of the current grid infrastructure limitations or challenges; how renewables and energy storage enable some of these solutions; and how hydrogen production and storage can provide synergies with the grid limitation issues and the need for productive use of excess renewable energy during non-peak hours.

Reviewer 2:

The reviewer noted that this proposed future work will address key shifts—such as ride hailing—that will impact future vehicle use and charging requirements. The reviewer stated exploring the potential impact of future mobility trends on PEV charging will be of significant interest in understanding the impact on the grid and the costs/benefits from both a system and consumer perspective.

Reviewer 3:

The reviewer commented there is not enough detail on the slides to evaluate planned work to scale California results to a national-level analysis. Proposed future work includes looking at the potential impacts of autonomous and ride-hailing fleets. These are interesting and important questions, and the reviewer encouraged the researchers to pursue these. However, even in the current individual ownership (and non-autonomous) model, there are additional case studies that could be considered. The reviewer noted how researchers suggested looking at a case with significantly more workplace charging. This seems important given that workplace charging is the second most common after home charging and could grow as more workplaces add infrastructure and/or more MUD residents purchase PEVs. The reviewer suggested that researchers might also consider side cases that incorporate additional public charging, particularly DC fast-charging and extreme fast-charging, which have different load profiles than residential and workplace charging. The reviewer said the project could also benefit from conducting sensitivities around key parameters for the vehicle mix (e.g., longer ranges, different battery electric vehicle/PHEV splits) as these could significantly impact charging behavior.

Question 5: Relevance—Does this project support the overall DOE objectives?

Reviewer 1:

The reviewer agreed yes, this work can help researchers understand the potential energy, cost, and environmental benefits of advanced technology adoption.

Reviewer 2:

The reviewer commented that this project directly looks at the impact of PEVs on the electric grid and the impact on renewable energy utilization. This provides insights into the DOE objectives of reducing GHG emissions and petroleum consumption.

Reviewer 3:

The reviewer had no further comments.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked resources appear to be sufficient for the current questions in scope. Other issues have been raised in these comments that may require additional resources, or at least more collaboration with those who are studying these questions.

Reviewer 2:

The reviewer indicated that resources seem sufficient to meet stated milestones.

Reviewer 3:

The reviewer pointed out that while the presentation specific total funding and support for FY 2017, FY 2018 and FY 2019 levels were not. However, it appears that only a small amount of total project funds was used in prior years, so the remaining support is likely sufficient for the proposed work.

Acronyms and Abbreviations

ANL	Argonne National Laboratory
BEAM	Behavior, Energy, Autonomy, and Mobility
DC	Direct-current
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
EV	Electric vehicle
EVI-Pro	Electric Vehicle Infrastructure Projection
EVSE	Electric vehicle supply equipment
FCEV	Fuel cell electric vehicle
FOTW	Fact of The Week
FY	Fiscal year
GHG	Greenhouse gas
GREET	Greenhouse gas, Regulated Emissions, and Energy use in Transportation
HD	Heavy-duty
LCA	Life cycle analysis
LD	Light-duty
MD	Medium-duty
MUD	Multi-unit dwelling
NREL	National Renewable Energy Laboratory
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PEV	Plug-in electric vehicle
PHEV	Plug-in hybrid electric vehicle
R&D	Research and development
TEDB	Transportation Energy Data Book
TNC	Transportation network company
TOU	Time of use

VAN	Vehicle Analysis (VTO program)
VTO	Vehicle Technologies Office

9. Acronyms and Abbreviations

°C	Degrees Celsius
1.5 M LiFSI-TEP/BTFE	Lithium-ion battery electrolyte
3-D	Three-dimensional
3GAHSS	Third-Generation Advanced High-Strength Steel
A/F	Air/fuel
ABM	Activity-based model
ABMS	Agent-based modeling and simulation
ABR	Applied Battery Research for Transportation
AC	Alternating current, air conditioning
ACC	Adaptive cruise control, automated cruise control
ACEC	Advanced Combustion & Emissions Control
ACES	Automated, connected, efficient, and shared; automated, connected, electric, and shared
ACI	Advanced compression ignition
ACI-F	Advanced compression ignition: fuel effects
ADAS	Advanced driver assistance system
AEC	Advanced Engine Combustion
AES	Automated electric shuttle
AFDC	Alternative Fuels Data Center
AFIDA	Advanced fuel ignition delay analyzer
AFV	Alternative fuel vehicles
Ah	Ampere-hour
AI	Artificial intelligence
Al	Aluminum
Al_2O_3	Aluminum oxide (alumina)
ALD	Atomic-layer deposition

ALS	Advanced Light Source
AMBER	Advanced Model Based Engineering Resource
AMD	Automated mobility districts
AMFI	Additive-mixing fuel injection
AMR	Annual Merit Review
ANL	Argonne National Laboratory
ANN	Artificial neural network
APRF	Advanced Powertrain Research Facility
ARDL	Akron Rubber Development Laboratory
ARL	Army Research Laboratory
ARPA-E	Advanced Research Projects Agency-Energy
ASIL	Automotive Safety Integrity Level
ASR	Area-specific resistance
ATF	Automatic transmission fluid
ATM	Active traffic management
atm	Atmosphere
ATR	Attenuated total reflection
AV	Automated vehicle
AVL-18a	Fuel for engine testing
AVTC	Advanced Vehicle Technology Competitions
AZ31	Magnesium alloy
B	Magnetic-flux density
Ba	Barium
BAU	Business as usual
BEAM	Behavior, Energy, Autonomy, and Mobility
BEV	Battery electric vehicle
BH_{max}	Maximum energy product
BMR	Battery Materials Research

BNL	Brookhaven National Laboratory
BOL	Beginning of life
BP	Budget Period
Br	Bromine
Br	Residual induction
BTE	Brake thermal efficiency
BU	Binghamton University
C	Charge rate
C	Carbon
C_3H_6	Propene
C70	Fullerene molecule used as a conductor
CA50	Crank angle position at which 50% of heat is released
CAC	Cooperative automated control
CACC	Cooperative adaptive cruise control
CAE	Computer-Added Engineering
CAEBAT	Computer-aided engineering of batteries
CAFÉ	Corporate Average Fuel Economy
CAMP	Cell Analysis, Modeling, and Prototyping Facility
CAN	Controller area network
CAV	Connected autonomous vehicle, connected and automated vehicle
CBD	Carbon-binder domain
CD	Cylinder deactivation
Ce	Cerium
CE	Coulombic efficiency
CEI	Cathode-electrolyte interphase
CeO_2	Cerium oxide (ceria)
CF	Carbon fiber
CFC	Carbon fiber composites

CFD	Computational fluid dynamics
CFP	Capillary flow porometry
CFR	Constant-pressure flow rig
CFRP	Carbon fiber-reinforced polymer
CGI	Compacted graphite iron
CH_4	Methane
CHA	Chabazite
CHT	Conjugate heat transfer
CI	Compression ignition, conversion inflection
Cl	Chlorine
CLEERS	Cross-cut Lean Exhaust Emissions Reduction Simulations
CNG	Compressed natural gas
CNT	Carbon nanotubes
CO	Carbon monoxide
CO_2	Carbon dioxide
CoEx	Co-extrusion
COV	Coefficient of variation
CPC	Capacitive power coupler
CPEC	Close Proximity Electromagnetic Carbonization
CPU	Central processing unit
CR	Compression ratio
CRADA	Cooperative Research and Development Agreement
CRF	Combustion Research Facility
Crr	Coefficient of rolling resistance
CT	Computerized tomography
CTE	Coefficient of thermal expansion
Cu	Copper
CV	Connected vehicle

D	Dimension
DC	Direct current
DCFC	Direct-current fast-charging
DEER	Directions in Engine-Efficiency and Emissions Research
DEF	Diesel-exhaust fluid (urea)
DEGR	Dedicated exhaust gas recirculation
DEM	Discrete-element method
DEMS	Differential electrochemical mass spectroscopy
DFI	Ducted fuel injection
DFT	Density functional theory
DI	Direct-injection
DIC	Digital image correlation
DMC	Dimethyl carbonate
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DPF	Diesel particulate filter
DSF	Dynamic Skip Fire
DSR	Dynamic species reduction
DSRC	Dedicated short-range communications
dT	Change in temperature
DWPT	Dynamic wireless power transfer
E	Young’s modulus
E/S	Electrolyte/sulfur
E10	10% ethanol content gasoline
E85	85% ethanol content gasoline
EC	Ethylene carbonate
ECCE	Energy Conversion Congress and Exposition
ECN	Engine Combustion Network

Eco-CACC-I	Eco-Cooperative Adaptive Cruise Control-I
ECU	Engine control unit
ECV	Electric commercial vehicle
EDLi	Electrochemically deposited lithium
EDS	Electric drive system, energy-dispersive X-ray spectroscopy
EDV	Electric drive vehicle
EELS	Electron energy-loss spectroscopy
EEMS	Energy-Efficient Mobility Systems
EERE	Energy-Efficiency and Renewable Energy
EES	Electrochemical energy storage
EETT	Electrical and Electronics Technical Team
EGR	Exhaust gas recirculation
EHN	Ethylhexyl nitrate
EIS	Electrochemical impedance spectroscopy
ELSA	Euler-Lagrange spray atomization
ELT	Electrification Technologies
EM	Electromagnetic
EMN	Energy Materials Network
EMS	Energy management system
EPA	U.S. Environmental Protection Agency
EPR	Electron Paramagnetic Resonance
EUCAR	European Council for Automotive R&D
EV	Electric vehicle
EVI-Pro	Electric Vehicle Infrastructure Projection
EVSE	Electric vehicle supply equipment
EXAFS	Extended X-ray absorption fine structure
FAA	Federal Aviation Administration
FACE	Fuels for advanced combustion

FASTSim	Future Automotive Systems Technology Simulator
FBJ	Friction Bit Joining
FCA	Fiat Chrysler Automobiles
FCEV	Fuel cell electric vehicle
FE	Fuel economy
FEC	Fluoroethylene carbonate
FFRDC	Federally Funded Research and Development Center
FHWA	Federal Highway Administration
FLD	Forming Limit Diagram
FMCSA	Federal Motor Carrier Safety Administration
FOM	Figure of merit
FOTW	Fact of The Week
FSW	Friction Stir Weld
FT	Fuel and Lubricant Technologies
FTA	Federal Transit Administration
FTIR	Fourier transform infrared
FTP	Federal Test Procedure
FY	Fiscal Year
g/cc	Gram/cubic centimeter
GaN	Gallium nitride
GCI	Gasoline compression ignition
GDI	Gasoline direct injection
GHG	Greenhouse Gas
GM	General Motors
GM	General Motors
GPF	Gasoline particulate filter
GPS	Global positioning system
Gr	Graphite

GREET	Greenhouse gas, Regulated Emissions, and Energy use in Transportation
GTI	Gas Technology Institute
GVW	Gross vehicle weight
GWh	Gigawatt-hour
H	Magnetic-field strength
H_2	Hydrogen gas
HC	Hydrocarbon
HCCI	Homogeneous-charge compression ignition
Hci	Intrinsic coercive force
HCl	Hydrochloric acid
HCP	Hexagonal closed pack
HD	Heavy-duty
HDD	Heavy-duty diesel
HDV	Heavy-duty vehicle
HEDGE	High-Efficiency Dilute Gasoline Engine
HESM	Hybrid excitation synchronous machine
HEV	Hybrid electric vehicle
HIL	Hardware-in-the-loop
HOV	Heat of vaporization
HPC	High-performance computing
HP-RTM	High-Pressure Resin Transfer Molding
HRE	Heavy rare earth
HRR	Heat-release rate
HRTEM	High-resolution transmission electron microscopy
HT	Heat transfer
HTA	Hydrothermal aging
HV	High voltage
HWFET	Highway Fuel Economy Test

Hz	Hertz
I_0	Exchange current
IC	Internal combustion
ICE	Internal combustion engine
ICL	Irreversible capacity loss
ICME	Integrated Computational Materials Engineering
IEEE	Institute of Electrical and Electronics Engineers
IMEP	Indicated mean effective pressure
IMS	Insulated metal substrate
INL	Idaho National Laboratory
IPM	Interior permanent magnet
IR	Infrared
iTiC	International Transportation Innovation Center
ITS-JPO	Intelligent Transportation System Joint Program Office
JMI	Johnson Matthey Inc.
k	Thermal conductivity
KC	Kinetically controlled
kg	Kilogram
kW	Kilowatt
kW/l	Kilowatt per liter
kWh	Kilowatt-hour
L	Liter
L4	Level 4 high automation
L5	Level 5 full automation
LA	Los Angeles
LANL	Los Alamos National Laboratory
LATP	$Li_{1+x}Al_xTi_{2-x}(PO_4)_3$
lb	Pound

LBNL	Lawrence Berkeley National Laboratory
LCA	Life cycle analysis
LCD	Levelized cost of driving
LCO	Lithium cobalt oxide
LD	Light-duty
LDV	Light-duty vehicle
LES	Large eddy simulation
LESI	Lagrangian-Eulerian spark ignition
LFP	Lithium-iron phosphate
LHCE	Localized high-concentration electrolyte
Li	Lithium
Li_3NbO_4	Trilithium niobate
LIDAR	Light imaging, detection, and ranging
LiEDC	Lithium ethylene dicarbonate
LightMAT	Lightweight Materials Consortium
LIGO	Laser Interferometer Gravitational-wave Observatory
LiPON	Lithium phosphorous oxy-nitride
LiS	Lithium-sulfur
LLFC	Leaner lifted flame combustion
LLNL	Lawrence Livermore National Laboratory
LLS	Layered-layered spinel
LLTO	Lithium lanthanum titanate
LLZMO	Lithium lanthanum zirconium molybdenum oxide
LLZO	Lithium lanthanum zirconate
LMO	Lithium manganese oxide
LNG	Liquefied natural gas
LNMO	Lithium nickel manganese oxide
LNRO	$Li_{1.2}Ni_{0.2}Ru_{0.6}O_2$

LRLO	Lithium-rich layered oxide
LSTM	Long short-term memory
LT	Low-temperature
LTAT	Low-temperature aftertreatment
LTC	Low-temperature combustion
LTC	Low-temperature carbonization
LTGC	Low-temperature gasoline combustion
LTO	Lithium titanate
m/s	Meters per second
M2M	Michigan to Montana
MA3T	Market Acceptance of Advanced Automotive Technologies
MaaS	Mobility-as-a-system, mobility-as-a-service
mAh/g	Milliampere-hour/gram
MCCI	Mixed-mode compression ignition
MD	Molecular dynamics
MD	Medium-duty
MDV	Medium-duty vehicle
MEP	Mobility energy productivity
MERF	Materials Engineering Research Facility
mg	Milligram
Mg	Magnesium
mg/cm^2	Milligram/square centimeter
MgO	Magnesium oxide
MGOe	Megagauss Oersted
MHz	Megahertz
MIT	Massachusetts Institute of Technology
ML	Machine learning
ml	Milliliter

mm	Millimeter
MMC	Metal-matrix composites
MMLV	Multi Material Lightweight Vehicle
Mn	Manganese
Mo	Molybdenum
MOC	Model predictive control
MON	Motor octane number
MORPC	Mid-Ohio Regional Planning Commission
MOU	Memorandum of Understanding
MOVES	Motor Vehicle Emission Simulator
MPC	Model-predictive control
MPO	Metropolitan Planning Organization
M_S	Saturation magnetization
MS	Mass spectroscopy
MUD	Multi-unit dwelling
N/P	Ratio of negative to positive electrodes
Na	Sodium
NA	North American
NA	Naturally aspirated
Nb	Niobium
NCA	Nickel cobalt aluminum oxide
NCF	Non-crimp fabrics
NCM	Nickel cobalt manganese oxide
NCMA	$Li_{1.0}Ni_{0.8}[Mn, Co, Al]_{0.2}O_2$
NDA	Non-disclosure agreement
NH_3	Ammonia
NHTSA	National Highway Traffic Safety Administration
Ni	Nickel

nm	Nanometer
NMC	Nickel manganese cobalt oxide
NMP	N-methylpyrrolidone
NMR	Nuclear magnetic resonance
NO_x	Oxides of nitrogen
nPDF	Neutron pair distribution function
NPP	Nuclear power plant
NRC	National Research Council of Canada
NREL	National Renewable Energy Laboratory
NSF	National Science Foundation
NVH	Noise, vibration, and harshness
O_2	Oxygen
OAS	Open architecture software
OBD	On-board diagnostics
O-D	Origins-destination
ODOT	Ohio Department of Transportation
Oe	Oersted
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
OS	Octane sensitivity
OTA	Over-the-air
P	Pressure
PAH	Polycyclic aromatic hydrocarbon
Pd	Palladium
PDF	Pair distribution function
PDVF	Polyvinylidene difluoride
PEO	Polyethyleneoxide
PEV	Plug-in electric vehicle

PF	Power factor
PGM	Platinum group metals
PHEV	Plug-in hybrid electric vehicle
PI	Principal Investigator
PLD	Pulsed laser deposition
PM	Particulate matter
PMI	Particulate matter index
PN	Particle number
PNA	Passive NO_X adsorber
PNNL	Pacific Northwest National Laboratory
POLARIS	Planning and Operations Language for Agent-based Regional Integrated Simulation
PSU	Pennsylvania State University
Pt	Platinum
PTFE	Poly(tetrafluroethylene)
PTO	Power takeoff
Q&A	Question and answer
R&D	Research and development
R2R	Roll-to-roll
R_c	Thermal contact resistance
RCEM	Rapid compression expansion machine
RCM	Rapid compression machine
RD587	88-octane research gasoline
RL	Reinforcement learning
RMS	Root mean square
$ROCO_2Li$	Lithium alkyl carbonate
ROI	Return on investment
RON	Research octane number
rpm	Revolutions per minute

RTM	Resin transfer molding
RVE	Representative volume element
s	Second
S	Sulfur
S/cm	Siemen per centimeter
SAE	Society of Automotive Engineers
SCAQMD	South Coast Air Quality Management District
SCO	Selective catalytic oxidation
SCO	Spray/combustion—optical imaging
SCR	Selective catalytic reduction
SCRF	Selective catalytic reduction on filter
SEI	Solid electrolyte interface
SEISta	Silicon Electrolyte Interface Stabilization
SEM	Scanning electron microscope
Si	Silicon
SI	Spark ignition
SiC	Silicon carbide
SIMS	Secondary ion mass spectroscopy
SiO_x	Silicon oxides
SLAC	Stanford Linear Accelerator Center
SMART	Systems and Modeling for Accelerated Research in Transportation
SMC	Sheet molding compound
SME	Subject matter expert
SNL	Sandia National Laboratories
SOC	State of charge
SOH	State of health
SPRINGS	Statistical Planning for Resilience in Next Generation Systems
SS	Sprays—simulation

SSE	Solid-state electrolyte
SSRL	Stanford Synchrotron Radiation Lightsource
SSRM	Scanning spread resistance microscopy
ST	SuperTruck
ST1	SuperTruck I
ST2	SuperTruck II
STEM	Scanning transmission electron spectroscopy
STEM	Science, technology, engineering, and math
SUV	Sport utility vehicle
SVTrip	Stochastic vehicle trip
SX	Sprays—X-ray imaging
sXAS	Soft X-ray absorption spectroscopy
T	Tesla
T50	Temperature at which 50% conversion occurs
T90	Temperature at which 90% conversion occurs
Ta	Tantalum
TARDEC	U.S. Army Tank Automotive Research, Development and Engineering Center
TAZ	Travel analysis zone
TBC	Thermal barrier coating
TCO	Total cost of ownership
TEDB	Transportation Energy Data Book
TEGDME	Tetraethyleneglycoldimethane
TEM	Transmission electron microscopy
TERS	Tip-enhanced Raman spectroscopy
Ti	Titanium
TI	Technology Integration
TiAl	Titanium aluminides
TiB_2	Titanium diboride

TiO_2-S	Titanium dioxide-sulfur
TJI	Turbulent jet ignition
TM	Transition metal
TMPSi	Trimethoxypropylsilane
TNC	Transportation network company
TOU	Time of use
TPG	Thermal pyrolytic graphite
TPI	Transient plasma ignition; tuned port injection
TRANSNET	Traveler Response Architecture using Novel Signaling for Network Efficiency in Transportation
TRL	Technology readiness level
TSDC	Transportation Secure Data Center
TTFP	Tris(2,2,2-trifluoroethyl) phosphite
TTI	Texas Transportation Institute
TWC	Three-way catalyst
TXM	Transmission X-ray microscope
U.S.	United States
U.S. DRIVE	United States Driving Research for Innovation for Vehicle efficiency and Energy sustainability
UC	University of California
UCC	Ultra-conductive copper
UCLA	University of California at Los Angeles
UCSD	University of California at San Diego
UDDS	Urban Dynamometer Driving Schedule
UE	User equipment
UHSS	Ultra-High Strength Steels
UIC	University of Illinois at Chicago
UM	University of Michigan
UMD	University of Maryland

UNR	University of Nevada, Reno
UPS	United Parcel Service
USABC	U.S. Advanced Battery Consortium
USAMP	United States Automotive Materials Partnership
USCAR	United States Council for Automotive Research
UT-Austin	University of Texas at Austin
UV	Ultraviolet
UW	University of Washington
UW	University of Wisconsin – Madison
V	Volt
V	Vanadium
V2G	Vehicle-to-grid
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
VAN	Vehicle Analysis (VTO program)
VATT	Vehicle average travel time
VCR	Variable compression ratio
VERIFI	Virtual Engine Research Institute and Fuels Initiative
VIBE	Virtual integrated battery environment
VIL	Vehicle-in-the-loop
VMT	Vehicle miles traveled
VTO	Vehicle Technologies Office
WBG	Wide bandgap
WFSM	Wound-field synchronous machine
Wh	Watt-hour
Wh/kg	Watt-hour per kilogram
WHR	Waste heat recovery
XAS	X-ray absorption spectroscopy

XPS	X-ray photoelectron spectroscopy
XRD	X-ray diffraction spectroscopy
YS	Yield strength
YSI	Yield sooting index
ZEK100	Magnesium alloy
Zero-RK	Zero-order reaction kinetics
Zr	Zirconium
ZrO_2	Zirconium dioxide (zirconia)

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