July 16, 2010

Presented at the California Energy Commission's 2010-2011 Advisory Committee Meeting and Public Hearing for the Alternative and Renewable Fuel and Vehicle Technology Program

Comments on the
Draft of the 2010-2011 Investment Plan for the
Alternative and Renewable Fuel and Vehicle Technology Program

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Thank you for the opportunity to speak to the California Energy Commission's Transportation Committee on the analysis and recommendations in the Draft of the 2010-2011 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program.

My name is Joan Ogden. I am professor of Environmental Science and Policy at UC Davis and direct the Sustainable Transportation Energy Pathways (STEPS) program at the campus' Institute of Transportation Studies. I would like to provide input on analysis and research under the UC Davis STEPS program (mentioned on p. 104 of the Draft Plan) and its relevance to the Alternative and Renewable Fuel and Vehicle Technology Program.

The STEPS program is a multi-year, interdisciplinary research effort, launched at UC Davis in 2007. STEPS is funded by a diverse consortium of 22 industry and government sponsors, supporting a broad research program involving about 15 faculty and 25 graduate students. The objectives of the STEPS program are:

(1) to develop the theory, tools and methods that allow for *self-consistent* and *transparent* comparisons of promising alternative energy and vehicle pathways—*hydrogen*, *biofuels, electricity and fossil fuels*.
(2) to inform the policy process and public knowledge through research, workshops, white papers, and to assist our public and private sponsors by providing tools and knowledge concerning sustainable transportation alternatives.
(3) To analyze potential transitions in the transportation sector by addressing markets and consumer behavior, engineering and economics of vehicles and fuel infrastructure systems, societal and lifecycle environmental impacts (climate change, air quality, energy security) and public policy.

Details about STEPS program scope and achievements will be submitted to the written record.

The STEPS program is conducting research of high relevance to CEC's Alternative and Renewable Fuel and Vehicle Technology Program. For example, STEPS researchers have

developed a number of sophisticated hydrogen infrastructure models and case studies for specific US areas, with a focus on studying hydrogen rollout strategies in California.

These STEPs studies utilize detailed GIS databases such as road networks, census data for population distribution, urban traffic distribution, and locations of gasoline stations and other energy infrastructure in order to design, site and determine costs for the most appropriate hydrogen infrastructure for the given region or city. We have developed an extensive database on cost and performance of hydrogen infrastructure technologies and hydrogen system design.

STEPS hydrogen models simulate alternative hydrogen infrastructure rollout scenarios for California and the US considering:

- Different hydrogen station and vehicle placement scenarios for specific regions
- Strategic station siting to assure consumer convenience
- Analysis of different hydrogen supply pathways and delivery modes with respect to technical performance, cost, GHG and air pollutant emissions, and primary energy use (pathways include renewable hydrogen and fossil w/ CCS).
- Idealized layout of hydrogen delivery systems, such as trucks and pipelines.
- Estimates of hydrogen transition costs and benefits

STEPS hydrogen infrastructure models have been employed by industry and the National Academies in recent hydrogen transition analyses.

Analogous STEPS infrastructure studies are underway for biofuels and electric vehicles.

We look forward to working with the committee on analysis of hydrogen and other infrastructure scenarios for California. I would be happy to answer any questions about STEPS research.

Thank you.

Sincerely,

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SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS
An Institute of Transportation Studies Program

PROGRAM SUMMARY

Sustainable Transportation Energy Pathways Program

Institute of Transportation Studies
University of California, Davis
August 2009

The UC Davis Institute of Transportation Studies (ITS-Davis) launched the *Sustainable Transportation Energy Pathways* (STEPS) *Program*, a four-year, multi-disciplinary research effort, in 2007. The overarching objectives of the STEPS program are (1) to develop the theory, tools and methods that allow for *self-consistent* and *transparent* comparisons of promising alternative energy and vehicle pathways; and (2) to apply these tools and methods in comparative assessments of four general transportation energy pathways—*hydrogen*, *biofuels, electricity and fossil fuels*.

The goals of the STEPS program are to inform the public debate and to assist our public and private sponsors by providing tools and knowledge concerning sustainable transportation alternatives. The program carefully analyzes potential transitions in the transportation sector by addressing markets and consumer behavior, engineering and economics of vehicles and fuel infrastructure systems, societal and lifecycle environmental impacts (climate change, air quality, energy security) and public policy. Our intent is to generate a strong understanding and solid foundation of knowledge for companies and government agencies analyzing technology, investment and policy options.

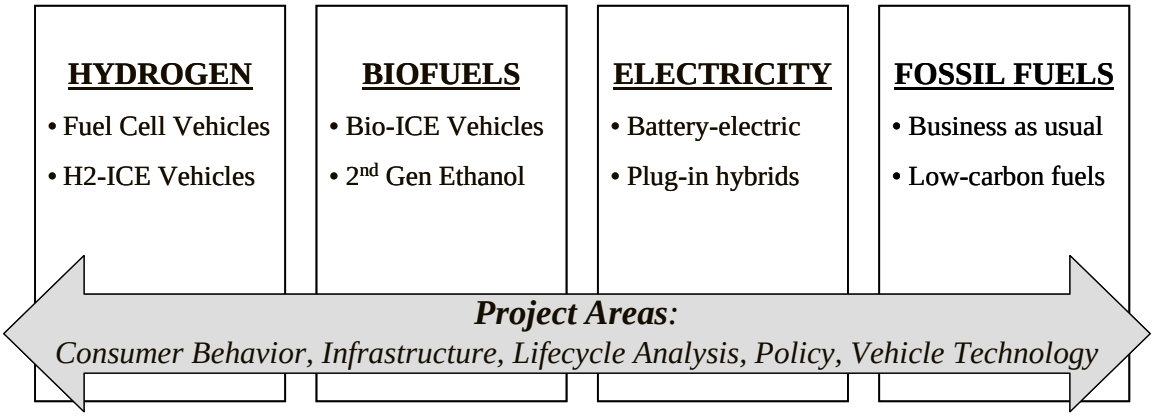

***Figure 1**: STEPS Research Scope and Project Areas—*
Program organized into energy tracks with comparative analysis in project areas

STEPS Builds on ITS-Davis Research

Over the past 12 years, ITS-Davis has developed an international reputation for its consortium-based transportation research. The STEPS Program extends two previous ITS-Davis research programs: the *Fuel Cell Vehicle Modeling Program,* which focused on fuel cell vehicles, and the

Hydrogen Pathways Program, which focused on hydrogen fuel.[1] The research scope of the STEPS Program allows comparisons across a greater number of alternative fuel and vehicle combinations, with the goal of enabling government agencies and industry to evaluate a broader range of future transportation options. An expanded description of current projects and program sponsors can be found on our program website (www.steps.its.ucdavis.edu).

STEPS research is leveraged by UC Davis's growing commitment to alternative fuels, renewable energy and transportation energy research. In 2007 the campus selected energy as one of five key research thrusts for the university. Through the UC Davis Energy Initiative, the university has already brought in new faculty with expertise in lifecycle analysis, biofuels and fuel cells and is committed to hiring a total of 15 new faculty in the energy area. Other UC Davis energy-related initiatives include the Energy Efficiency Center, the California Biomass Collaborative, the Plug-in Hybrid Electric Vehicle (PHEV) Research Center and other programs at ITS-Davis.[2]

Program Overview

The STEPS Program draws upon research methods from a broad range of academic fields, including vehicle engineering and design, systems analysis and operations research, chemical and mechanical engineering, lifecycle cost and emissions analysis, market research, sociology and anthropology, economics and business strategy, and policy and political analysis. Our research team includes 15 Ph.D.-level faculty and research scientists and 25 graduate students, drawn from a variety of departments. The focus is on understanding transitions toward a more sustainable transportation system, one that will rely on more than one solution to meet energy supply and greenhouse gas objectives. We consider both near-term and long-term technologies to analyze possible paths forward. A key issue is to understand how one technology path can enable another, and how multiple technologies can be either synergistic or competitive.

Scope of STEPS Projects

Figure 1 above summarizes the four transportation energy tracks and indicates the types of projects for comparative analysis. They include:

- **Hydrogen.** Continuing research conducted under the Hydrogen Pathways Program, we are exploring new areas such as hydrogen/electricity systems, regional transition case studies, well-to-tank energy and emissions modeling and enhancing key hydrogen pathways models for infrastructure development strategies.
- **Biofuels.** This track builds upon UC Davis's current work within the California Biomass Collaborative and the considerable agricultural and biological expertise of the university. The biofuels track includes analysis of various biorefinery production systems, infrastructure strategies, environmental and land-use impacts and vehicle analysis.

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[1] From 1998 through 2002, the Fuel Cell Vehicle Modeling Program (FCVMP) developed advanced fuel cell vehicle simulation models of a variety of fuel and powertrain combinations, providing a comparison tool for sponsors to use for their in-house evaluations. Over the course of five years, the program supported nine graduate students and several faculty, resulting in 60 publications and presentations. The program was supported by 20 corporate sponsors and two government agencies (http://www.its.ucdavis.edu/research/vehicletechnologies/fcvmp.html).

ITS-Davis conducted its next research consortium from 2003 through 2006—the Hydrogen Pathways Program (http://hydrogen.its.ucdavis.edu/). This program focused on understanding the potential transition to a hydrogen-based transportation system. The Hydrogen Pathways Program produced over 100 research publications, received several national awards for its contributions, educated over 20 graduate students and informed hydrogen policy at the state and national level. The program was supported by 16 corporate sponsors and 5 government agencies.

[2] Additional information on these other programs can be found on the ITS-Davis program website (www.its.ucdavis.edu).

- **Electricity.** Electricity production methods, total grid capacity and time-of-day charging impacts on the utility sector are studied for both plug-in vehicles and hydrogen production. Additionally, research is conducted on consumer behavior and preferences for electric drive attributes, including all-electric range and charging time. This work is leveraged by the UC Davis PHEV Research Center.
- **Fossil Fuels.** This track includes both the business-as-usual reference case, where conventional petroleum fuels continue to dominate transportation energy, and the evolution of fuels produced from other fossil fuel resources, including tar sands, oil shale and coal with carbon capture and sequestration.

STEPS Comparative Research Methods

To conduct robust comparative analyses among different energy and vehicle pathways, the STEPS Program's research is organized into cross-cutting comparative project areas (as indicated in Figure 1). A few of these are highlighted below.

- **Infrastructure Analysis.** Using geographic information system (GIS) analysis, mathematical optimization methods and resource assessment tools to study total supply chain costs for biofuels, hydrogen and electricity; comparing design, costs and GHG impacts for different fuel supply pathways for the production and delivery of liquid fuels and hydrogen.
- **Energy, Environmental and Cost Analysis.** Using lifecycle analysis tools, such as the UC Davis LEM & AVCEM models, to study and compare well-to-wheels energy use and emissions for fuel production and use in vehicles; studying broader sustainability impacts such as water resources and land-use changes.
- **Vehicle Technology Evaluation.** Using Matlab/Simulink vehicle system engineering modeling tools to evaluate PHEV battery and system design tradeoffs; comparing performance of PHEVs to fuel cell vehicles and battery electric vehicles.
- **Integrative Scenarios.** Integration of multiple alternatives into economy-wide models with the ability to simulate various policy options into the future, incorporating regional differences, resource availability, market dynamics and complete system interactions.

A Sampling of STEPS Projects and Early Results

In 2007 and 2008, STEPS researchers produced over 75 research publications and reports. A full list of our publications can be found on the program website (www.steps.its.ucdavis.edu). Included here are three examples of recent STEPS research projects.

Our scenario studies have shown the importance of a portfolio approach in reducing carbon emissions and gasoline use in transportation over the next few decades. In a recent study, STEPS researchers developed possible scenarios for meeting California's ambitious goal of reaching an 80% reduction in GHG emissions below 1990 levels by 2050. While no single mitigation option can meet the target alone, the goal can be met by utilizing a combination of technological and behavioral options.
(Yang, C., D. McCollum, R. McCarthy, and W. Leighty. 2008. 80-in-50 scenarios for deep reductions in GHG emissions from California transportation. Publication pending.)

The future role of PHEVs in meeting near-term or long-term energy and emissions goals depends not only on their technology (vehicle design and performance), but also on drivers' travel and refueling/recharging behaviors. In a recent survey-based analysis, STEPS researchers found that at least half of the survey respondents have modern electrical systems that would allow at-home vehicle recharging without costly retrofits. Although respondents showed interest in a range of possible PHEV benefits, the appeal of increased fuel economy ranked higher than a large all-electric

range or speed. These results may help inform decision-makers as PHEV battery specifications and goals are being evaluated.
(Axsen, J.and K. Kurani. 2008. The early U.S. market for PHEVs: Anticipating consumer awareness, recharging potential, design priorities and energy impacts. ITS-Davis Research Report UCD-ITS-RR-08-22.)

A STEPS analysis of gasoline use reveals that behavioral and structural factors over the past several decades have changed the responsiveness of U.S. consumers to gasoline price fluctuations (short-run elasticities are *reduced*). One implication of these findings is that gasoline taxes would need to be significantly larger today in order to achieve an equivalent reduction in gasoline consumption. This suggests that policies and technologies designed to improve fuel economy are likely becoming relatively more attractive as a means to reduce fuel consumption.
(Knittel, C., J. Hughes, and D. Sperling. 2008. Evidence of a shift in the short-run price elasticity of gasoline demand. *Energy Journal* 29(1): 113–134.)

Program Participation

The STEPS program has four funding cycles corresponding to calendar years 2007 through 2010. Program Sponsors provided $50,000 per year to participate for the first two years and will contribute $60,000 per year thereafter. Program Sponsors joining after the first two years must provide 40% back pay for each year while not a member. This policy recognizes the cumulative nature of the research and the past commitments of existing sponsors. For each calendar year during the program, ITS-Davis will invite sponsors to renew their participation; an up-front pledge for four years is not required.

Sponsorship Activities and Benefits

Program Sponsors are encouraged to participate in all program activities listed below. The level of participation will be decided independently by each sponsor.

- ***STEPS Advisory Committee*.** The committee meets at least once per year to advise the program's leadership on the coming year's research and program activities.

- ***Technical Workshops*.** Each year, at least one high-level, invitation-only research workshop will be held on critical technical issues and topics.

- ***Research Reports*.** Researchers will issue reports and working papers over the course of the program. These reports are provided immediately to Program Sponsors, often prior to publication.

- ***Research Bulletins*.** A quarterly newsletter for Program Sponsors and researchers highlights recent program news including research results, new projects and events.

- ***Website*.** The STEPS Program hosts a password-protected website. Program Sponsors have instant access to STEPS research and program information.

- ***Public Process Activities*.** In addition to events for our sponsors, special public process events are conducted. These include tutorial workshops for policymakers at the state and national levels and policy issue forums.

- ***Program Sponsor Advisors and Internships*.** Where there is interest, Program Sponsors and STEPS researchers interact closely on specific projects, arrange for student internships at Program Sponsor locations and host extended visits from Program Sponsors at ITS-Davis.

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SUSTAINABLE TRANSPORTATION ENERGY PATHWAYS
An Institute of Transportation Studies Program

PROGRAM ACHIEVEMENTS 2007–2009: PUBLICATIONS, EVENTS and AWARDS

Sustainable Transportation Energy Pathways (STEPS) Program

Institute of Transportation Studies
University of California, Davis
January 2010

Since 2007, STEPS researchers at the UC Davis Institute of Transportation Studies (ITS-Davis) have produced over 100 articles, research reports and major publications. In addition, the program has held four sponsor events and four policymaker outreach events in Sacramento, Davis, and Washington, DC.

STEPS Program publications, events and awards to date are summarized below. Please visit the STEPS website (http://www.steps.its.ucdavis.edu) for copies of selected publications.

PUBLICATIONS

Books and Chapters in Books

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EVENTS

Advisory Board Meeting
July 28, 2009 (Asilomar Conference Grounds, Pacific Grove, California)

Policy Symposium
March 10–11, 2009 (UC Davis campus)

This invitation-only event focused on policy solutions required to address transportation energy and climate change. The symposium was organized around four general policy categories, each necessary in a comprehensive policy approach: (1) RD&D and technology innovation policies, (2) pre-commercialization stimulation policies, (3) performance-based policies, and (4) broad market-based policies.

Policymaker Briefing
January 12, 2009 (U.S. Capitol Visitors Center, Washington, DC)

ITS-Davis conducts considerable analysis to support California's carbon emission reduction policies. Faculty from ITS-Davis provided this briefing to inform staff members from the House, Senate and federal agencies. The Institute presented four talks to explain the basis and current implementation stage of four key California low-carbon transportation strategies: its low carbon fuel standard (LCFS), a renewed consideration of feebates, PHEV roll-out strategies, and tools to support smart land use under SB 375.

Policymaker Briefing
October 18, 2008 (UC Davis campus)

Research Symposium
May 13–14, 2008 (UC Davis campus)

This research symposium was organized around two main themes: (1) possible scenarios for implementing future fuels and vehicles, and (2) assessing the status of key factors that enable them: technology, behavior, and resources.

Policy Symposium: Reducing Greenhouse Gas Emissions from Passenger Vehicles—What's Next?
April 21, 2008 (California EPA Building, Sacramento, California)

The California Air Resources Board and ITS-Davis held a special symposium about achieving reductions in greenhouse gases from California passenger vehicles.

Alternative Fuels Policy Briefing
October 15, 2007 (Cal EPA Building, Sacramento, California)

The UC Davis Alternative Fuels Policy Briefing was designed for anyone involved in transportation, energy, and climate change policy development. The presentations provided the most up-to-date information at a general level, making the event accessible for all policymakers, regardless of their experience with energy and climate change. Topics included transportation alternatives such as hydrogen and biomass fuels, and advanced hybrid vehicle technology.

Advisory Board Meeting
August 21, 2007 (Asilomar Conference Grounds, Pacific Grove, California)

Lifecycle Analysis Modeling Seminar
July 24, 2007 (UC Davis campus)

Moving Toward Sustainable Transportation: The Role of Academic Research
May 21-22, 2007 (UC Davis campus)

This event featured presentations from STEPS Program researchers as well as a few of the sponsor organizations on the subject of sustainable transportation. The STEPS Program research plan was presented, and there was dialogue regarding the important academic research questions for sustainable transportation development.

Policymaker Briefing
January 23, 2007 (U.S. Capitol, Washington, DC)

ITS-Davis researchers Anthony Eggert, Dan Sperling, Joan Ogden, and Tom Turrentine, along with U.S. DOE/ORNL senior scientist David Greene, briefed senior congressional and agency staff at the U.S. Capitol on January 23, 2007. The briefing, sponsored by Congressman Mike Thompson (D - CA), focused on transportation technologies and fuels that have the potential to dramatically reduce petroleum consumption and greenhouse gas emissions from the transportation sector.

PUBLIC PROCESS ACTIVITIES

International

Dan Sperling – Chair, Global Agenda Council on the Future of Mobility, World Economic Forum

Joan Ogden – Lead Author, IPCC Committee Special Report on Renewable Energy (2009–2010)

National

Dan Sperling – NRC/NAS committees on Transport, Climate, and Energy Efficiency

Dan Sperling – American Physical Society, Committee on Energy Efficiency

Dan Sperling – U.S. Congressional testimony on Low Carbon Fuel Standard

Dan Sperling – Meeting with White House Energy Staff (2009)

Joan Ogden – NRC/NAS committees for Hydrogen and Fuel Cells (2007–2008) and PHEVs (2009)

Joan Ogden – U.S. Department of Energy, Hydrogen Technical Advisory Committee

California

Dan Sperling – Leads UC Davis team on UC Low Carbon Fuel Standard reports (7 STEPS researchers contribute to reports)

Dan Sperling, Joan Ogden, Christopher Yang – California Commission on Science and Technology, California Energy Future Study (2009)

Bryan Jenkins, Nathan Parker – Western Governor's Association report on biofuels

Bryan Jenkins – Advisor to state on biomass energy and renewable energy

Joan Ogden – California Air Resources Board Economic and Technical Advisory Panel for AB 32

Joan Ogden, Andrew Burke – ZEV regulation public workshop at California Air Resources Board

Christopher Knittel – California Air Resources Board Economic and Allocation Advisory Committee for AB 32

Christopher Knittel – Part of UC Davis/UC Berkeley team developing RECs for California "feebate" program

Christopher Knittel – Part of UC Davis/UC Berkeley team developing RECs for California LCFS

Cynthia Lin – Appointed to California state economic advisory group

Sonia Yeh, Nicholas Lutsey – Modeling for California LCFS implementation

AWARDS

Abbas Ghandi
- 2009 UK Energy Research Centre Summer School Nomination

Jonathan Hughes
- 2007 Barry D. McNutt Award for Excellence in Automotive Policy Analysis (Transportation Research Board)

Bryan Jenkins
- 2009 Johannes Linneborn Prize for outstanding contributions to the development of energy from biomass
- 2009 Academic Bioenergy Pioneer Award (American Society of Agricultural and Biological Engineers)

Bryan Jungers
- 2008 McWick Technology Foundation Fellowship

Christopher Knittel
- 2008 University of California, Davis Chancellor's Fellow Award
- 2007 Barry D. McNutt Award for Excellence in Automotive Policy Analysis (Transportation Research Board)

Wayne Leighty
- 2008–2009 Edison International Energy Efficiency Fellowship
- 2008 Eno Transportation Foundation Fellowship
- 2008 *Friends of ITS-Davis* Outstanding Master's Thesis Award
- 2007–2008 Chevron Corporation Fellowship
- 2007–2008 GATE Center of Excellence Fellowship

Xuping Li
- 2008 Women's Transportation Seminar, Sacramento—Helene M. Overly Scholarship

Zhenhong Lin
- 2007 Scientific Committee of the Second World Congress of Young Scientists on Hydrogen Energy Systems Award, best paper in the strategic and socio-economic analysis session

Nicholas Lutsey
- 2009 Kinsella Memorial Prize (UC Davis College of Agricultural and Environmental Sciences)
- 2006–2007 UC Davis Sustainable Transportation Center Dissertation Fellowship

David McCollum
- 2009 International Institute for Applied Systems Analysis Young Scientists Summer Program Fellowship
- 2008 Dwight David Eisenhower Transportation Fellowship (U.S. Department of Transportation)
- 2007–2008 Achievement Rewards for College Students (ARCS) Fellowship
- 2007 *Friends of ITS-Davis* Outstanding Master's Thesis Award
- 2006–2007 Chevron Corporation Fellowship

Geoff Morrison
- 2009 Dwight David Eisenhower Transportation Fellowship (U.S. Department of Transportation)

Colin Murphy
- 2008 AAH Fellowship
- 2008 Dwight David Eisenhower Transportation Fellowship (U.S. Department of Transportation)

Michael Nicholas
- 2007 Barry D. McNutt Award for Excellence in Automotive Policy Analysis (Transportation Research Board)

Joan Ogden
- 2007 University of California, Davis Distinguished Scholarly Public Service Award
- 2007 Barry D. McNutt Award for Excellence in Automotive Policy Analysis (Transportation Research Board)

Nathan Parker
- 2007 Council of University Transportation Centers Charles V. Wootan Award for Best Master's Thesis in Transportation Policy and Planning

Dan Sperling
- 2009 Robert Zweig Public Education Award of the National Hydrogen Association
- 2007 Barry D. McNutt Award for Excellence in Automotive Policy Analysis (Transportation Research Board)
- 2007 Portion of the Nobel Peace Prize for his contributions to the United Nations' Fourth Intergovernmental Panel on Climate Change (IPCC)

Yongling Sun
- 2009 Henry A. Jastro Endowment

Jonathan Weinert
- 2007 UC Davis Sustainable Transportation Center Outstanding Student of the Year
- 2007 Council of University Transportation Centers Student of the Year
- 2007 *Friends of ITS-Davis* Outstanding Dissertation Award

DEGREES GRANTED (current employer listed)

Obadiah Bartholomy, *M.S., Transportation Technology and Policy* (Sacramento Municipal Utility District)

Joel Bremson, *M.S., Transportation Technology and Policy* (Ph.D. candidate, TTP)

Gustavo Collantes, *Ph.D., Transportation Technology and Policy* (State of Washington)

Reid Heffner, *Ph.D., Transportation Technology and Policy* (Booz Allen Hamilton)

Ryohei Hinokuma, *M.S., Transportation Technology and Policy* (Japanese External Trade Organization)

Jonathan Hughes, *Ph.D., Transportation Technology and Policy* (CU Boulder)

Zhenhong Lin, *Ph.D., Civil and Environmental Engineering* (Oak Ridge National Laboratory)

Wayne Leighty, *M.S., Transportation Technology and Policy; M.S., Agricultural and Resource Economics* (Ph.D. candidate, TTP)

Nicholas Lutsey, *Ph.D., Transportation Technology and Policy* (International Council on Clean Transportation)

Ryan McCarthy, *Ph.D., Transportation Technology and Policy* (California Commission on Science and Technology)

David McCollum, *M.S., Transportation Technology and Policy; M.S., Agricultural and Resource Economics* (Ph.D. candidate, TTP)

Michael Nicholas, *Ph.D., Transportation Technology and Policy* (ITS-Davis)

Nathan Parker, *M.S., Transportation Technology and Policy* (Ph.D. candidate, TTP)

Brent Riffel, *M.S., Transportation Technology and Policy* (Lifecycle Associates)

Guihua Wang, *Ph.D., Civil and Environmental Engineering* (California Air Resources Board)

Jonathan Weinert, *Ph.D., Transportation Technology and Policy* (Chevron)

Brett Williams, *Ph.D., Transportation Technology and Policy* (UC Berkeley)