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California
Energy Commission
Research & Development

Request for Public Comments on the Preliminary Draft Research Roadmap

Energy Research and Development Division

Silvia Palma-Rojas, PhD

June 28, 2019

Webinar Objective

California Energy Commission staff is facilitating this webinar to request public comments on the research and development (R&D) opportunities identified for the Electric Program Investment Charge (EPIC) research roadmap on renewable energy generation technologies for utility-scale applications.

Research Roadmap

Develop an actionable research roadmap that describes prioritized investment opportunities to increase the cost competitiveness, flexibility, and reliability of renewable energy generation in California.

The research roadmap will be used to strategically target future EPIC investments to provide optimal benefits to investor-owned utility (IOU) electric ratepayers, and maximize the use of public R&D investments.

CEC Administered EPIC Funding

Applied Research and Development

Applied Research and Development includes activities to support pre-commercial technologies and approaches at applied lab-level or pilot-level stages.

Technology Demonstration and Deployment

Technology Demonstration and Deployment involves installation and operation of pre-commercial technologies or strategies at a scale that will reflect actual operating, performance, and financial characteristics and risks.

Market Facilitation

Market Facilitation focuses on a range of activities, such as commercialization assistance, local government regulatory assistance and streamlining, market analysis, and program evaluation to support deployment and expand access to clean energy technology and strategies.

Submitting Comments

Please go to CEC electronic commenting system

https://efiling.energy.ca.gov/Ecomment/Ecomment.aspx?docketnumber=19-ERDD-01

Add Comment

Docket #: 19-ERDD-01 Project Title: Research Idea Exchange

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Written comments will be received by the Energy Commission through July 12, 2019.

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PRELIMINARY DRAFT RENEWABLE ENERGY GENERATION RESEARCH ROADMAP

Public Comment Webinar,
June 28, 2019

Sabine Brueske, sbrueske@energetics.com

WEBINAR HOSTS

- Silvia Palma-Rojas

  Energy Commission, Commission Agreement Manager (CAM)
- Sabine Brueske

  Energetics, Project Manager
- Joan Pellegrino

  Energetics, Facilitator
- Harrison Schwartz

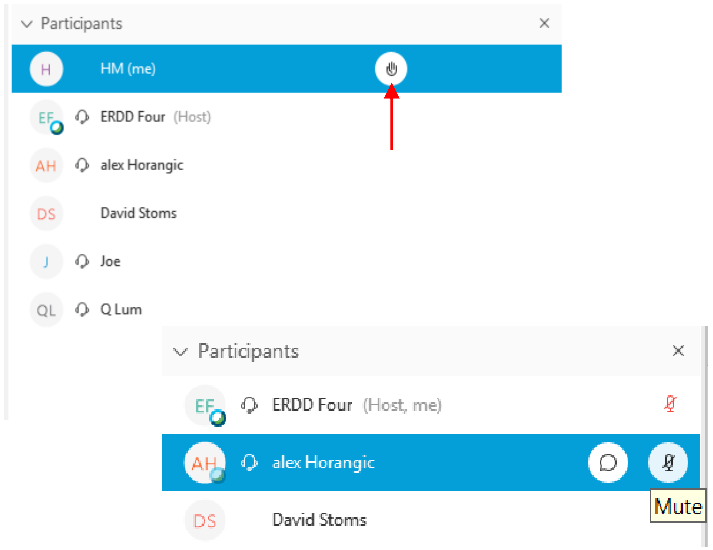
  Energetics, Project Analyst

WEBINAR AGENDA

10:00 am Introduction to Roadmap Project

10:15 am Facilitated Discussion

- 10:15 Photovoltaic Solar
- 10:30 Concentrated Solar
- 10:45 Land-Based Wind
- 11:00 Offshore Wind
- 11:15 Bioenergy
- 11:30 Geothermal
- 11:45 Small Hydropower
- 12:00 Grid Integration
- 12:15 Energy Storage



12:30 Closing

ROADMAP PROJECT OBJECTIVE

This roadmap is intended to identify, describe, and prioritize research, development, demonstration, and deployment (RDD&D) **technology opportunities that have potential to achieve higher penetrations of renewable energy** into California's electricity grid.

Working with stakeholders and subject matter experts to identify:

- Significant barriers to achieving greater use of renewable energy and storage in California
- Current research efforts at both the state and federal level that are addressing these knowledge gaps
- Research gaps that may be addressed by the Electric Program Investment Charge (EPIC) program
- Prioritizing future research needs in the near (1 to 3 years), mid-term (3 to 5 years), and long-term (>5 years)
- Indicators of success for renewable energy resource technologies and strategies
- Performance and cost targets, and other metrics

PROJECT TEAM

This Roadmap is led by **Energetics**, with valuable contributions from several subcontractors: **Center for Sustainable Energy**, **DAV Energy**, **Renewable Energy Consulting Services Inc.**, **Solar Power Consulting**, and **TSS Consultants**

Siliva Palma-Rojas managed this project for the California Energy Commission and provided valuable feedback and guidance throughout the effort.

Many thanks to the Technical Advisory Committee for their review and feedback on this project:

Cara Libby, Senior Technical Leader, Electric Power Research Institute	**Kevin Smith, Asset Management & Operating Services, DNV GL**
Dara Salour, Program Manager, Alternative Energy Systems Consulting	**Kurt Johnson, Chief Executive Officer, Telluride Energy**
Greg Kester, Director of Renewable Resource Program, California Association of Sanitation Agencies	**Lenny Tinker, Acting Photovoltaics Program Manager, U.S. Department of Energy, Solar Energy Technologies Office**
Jan Kleissl, Associate Director, University of California, San Diego, Center for Energy Research	**Robert Baldwin, PhD, Principal Scientist, National Renewable Energy Laboratory**
Julio Garcia, Geothermal Production Analysis Manager, Calpine	**Terra Weeks, Advisor to the Commissioner, California Energy Commission**

METHODOLOGY OF ROADMAP PROJECT

37 Interviews

- Technical Assessment

7 Surveys

7 Webinars

- Preliminary Draft Report

2 Public Webinars

Roadmap Report

June 28 - Public Comment

TBD date - Findings

PARTICIPATION IN ROADMAP METHODOLOGY

	Solar	Wind	Bioenergy	Geothermal	Small Hydro	Grid Integration	Energy Storage	Wave Power*	Total
Interviews	6	8	6	5	4	5	3	2	39
Survey Respondents	10	8	12	10	5	11	6	0	62
Webinar Participants	13	13	8	9	8	10	14	0	75
Unique Participants All Activities	19	21	21	17	13	22	18	2	114**

* Wave Power is not included in the Roadmap as an independent technology area. The technology was explored understanding that the TRL is very low for most wave technologies.

** Total Unique Participants sum is not equal to the sum of all topic areas since some participants were involved in multiple topic areas.

RESEARCH ROADMAP: TECHNOLOGY AREAS

- Solar (PV and CSP)
- Land-Based Wind
- Offshore Wind
- Bioenergy
- Geothermal
- Small Hydropower
- Grid Integration
- Energy Storage

STRUCTURE OF WEBINAR

- Discussion portion of webinar will be broken in to nine 15 minute topics
- Attendees are welcome to join only selected portions of discussion (see agenda)
- Today we will be discussing 20 recommended initiatives identified in the Preliminary Draft (see future Roadmap for full list of technologies and initiatives identified)
- Facilitator will guide us through questions while comments collected in real time

FACILITATED DISCUSSION TOPICS

10:15 am Facilitated Discussion

- 10:15 Photovoltaic Solar
- 10:30 Concentrated Solar
- 10:45 Land-Based Wind
- 11:00 Offshore Wind
- 11:15 Bioenergy
- 11:30 Geothermal
- 11:45 Small Hydropower
- 12:00 Grid Integration
- 12:15 Energy Storage

MATERIALS FOR REFERENCE

(accessible on the Energy Commission Research Idea Exchange docket)

Now:

- Technical Assessment
- Preliminary Report

Next Week:

- June 28 Public Webinar Slides

Future Date:

- Roadmap Report

UNIVERSAL CHALLENGES REQUIRING BROAD STAKEHOLDER INVOLVEMENT

- **Resource Availability (Utility-Scale System Permitting)**
  - Permitting issues related to land development and air quality prevent installations of renewable technologies at certain locations in the state.
  - Wind, solar, and bioenergy are most impacted but all renewable technologies could benefit from permitting relief
- **Resource Valuation**
  - Ancillary benefits of renewables such as lowering emissions and grid services are not valued by energy markets.
  - The current market structure only incentivizes the lowest cost energy sources which could lead to over-deployment of solar.
- **Technology Lock-in (Stymied Innovation)**
  - The scale of investment required for electric grid improvements leads to a comfort with existing technologies that prevents the transition of new technologies from pilot to full-scale deployment.

SOLAR PV OVERVIEW

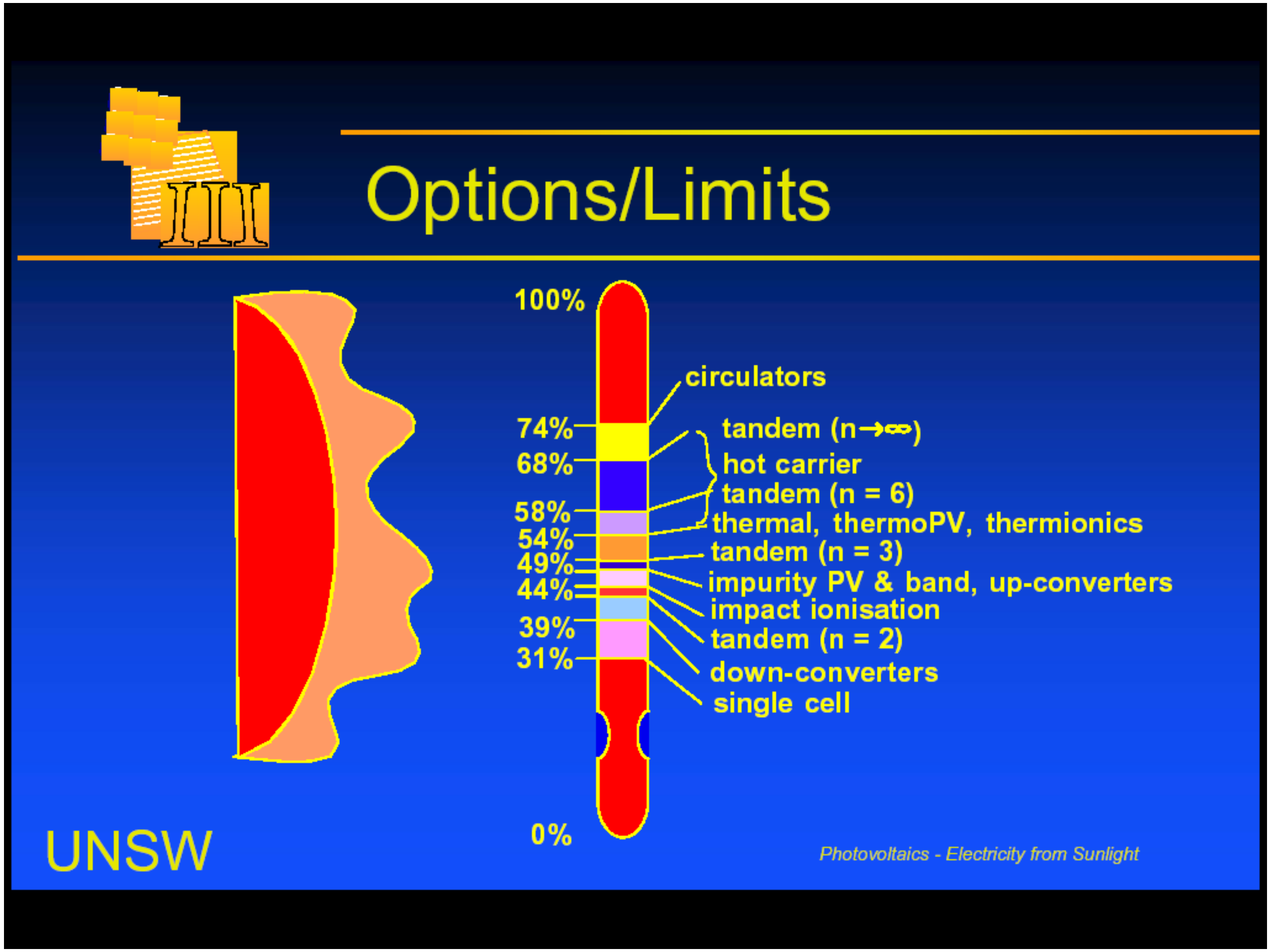
Solar PV provides the most energy of any renewable resource in California and has the most installed capacity.

- Current Baseline:
  - 2018 CA Capacity Factor: 26.5%
- Best in Class
  - Capacity Factor: ~33%
- Cost Targets: (Kansas city data point used by DOE)

	DOE FEDERAL FY 2017	FY 2018	FY 2019	2030 Target
Photovoltaic (PV)	7 cents/kWh (exceeded, 6)	6 cents/kWh	5.5 cents/kWh	3 cents/kWh
Solar + Storage	$1.96/Wdc	n/a	$1.65/Wdc	$1.45/Wdc

Wdc: Watts Direct Current

COMPARISON OF THEORETICAL SOLAR ENERGY CONVERSION EFFICIENCIES



By M. Green, from [*Feasibility of High-Efficiency Photovoltaics* Breakthrough *Research*, EPRI Palo Alto, CA, and California Energy Commission, Sacramento, CA: 2005. 1012872.]

SOLAR PV - RECOMMENDED INITIATIVE#1

Initiative 2.1: Deploy Thin Film and Tandem Material PV Cells

Description and Characteristics	Thin-film and Tandem-Junction PV technologies offer significant potential advantages over current crystalline silicon single-junction PV in terms of lower manufacturing costs, less material usage, and higher conversion efficiency. Achieving these, however, will require substantial field experience as well as manufacturing scale-up in addition to further laboratory development. **This initiative would establish field testing programs to accelerate acquisition of real-world experience with novel technologies** having such promise. This experience is vital for transferring laboratory advances toward commercial products.
Technology Baseline, Best in Class	Present-day commercial crystalline silicon PV modules have narrowed the gap between practical and theoretical performance such that future gains in LCOE will come only from further economies of larger-scale manufacturing and deployment. Meanwhile, thin-film technologies have shown increasing laboratory performance, but have not achieved the manufacturing scale needed to demonstrate their potential cost advantages.
Impacts	Thin-film PV devices have **potentially lower costs** due to better manufacturing scalability and lesser use of expensive materials than crystalline silicon devices. Tandem-junction PV technologies, which also may be thin-film, have substantially **higher theoretical efficiency limits** than crystalline silicon's, which translates into significantly lower energy cost potential.
Metrics and/or Performance Indicators	Metrics of success for these test deployments would include demonstration of specific failure mechanisms to aid in improved manufacturing as well as greater durability of subsequent deployments.
Success Timeframe	Long term. Ultimate success is likely in ten years or more, but nearer term useful results would also be likely.

SOLAR PV - RECOMMENDED INITIATIVE#2

Initiative 2.2: Reduce Capital Costs of PV by Improving Cell Recycling

Description and Characteristics	Commercial PV modules have expected service lives that are much longer than essentially all of the product deployed to date. As such, end-of-life issues have not been given major emphasis. However, these aspects of the technology will inevitably arise as the larger-scale systems now in use reach retirement. This initiative is designed to get in front of **potential environmental damage caused by improper salvage and recycling**.
Technology Baseline, Best in Class	Commercial crystalline silicon PV modules typically contain some amounts of potentially hazardous materials such as copper, lead, silver, and heavy metals, as well as significant quantities of plastic and glass contaminated with metals and organic compounds. Cost-effectively separating these materials into viable recycling streams is an unmet challenge.
Impacts	Successful application of the results of this initiative will **substantially reduce PV decommissioning costs** while safeguarding the **environment** from hazardous material disposal.
Metrics and/or Performance Indicators	Useful metrics for this initiative include quantitative assessments of **cost reductions** versus current practices in recycling PV modules and estimates of reduced **impacts on landfills** due to improved recovery of spent materials.
Success Timeframe	True success of this initiative awaits the retirement of the many gigawatts of PV recently deployed, which will take well over a decade. However, smaller-scale benefits may be achieved sooner by applying new techniques to other recycling processes.

SOLAR PV INITIATIVE DISCUSSION

Q1 - Are these research initiatives the right ones for cost and technology breakthroughs for utility-scale renewable energy generation?

Q2 - What are the cost/performance targets for each technology that should be considered for California?

Q3 - Are there any gaps in these initiatives?

NOTES – PV SOLAR

Right initiatives for cost and technology breakthroughs?		
Initiative #2, cell recycling, is of interest	Tandem could be used to reduce operating cost, is this small scale deployment (current solicitation challenging in response, mixture of forward thinking yet commercial stage)	
Reword, cell recycling should be modular recycling – how to handle big picture (transportation costs)		
Cost and performance targets that should be considered?		
Cost factors seemed high for CA (nat'l avg shown)		
Gaps in these initiatives?		
Thermal management of panels, reducing heat degradation	Pairing solar with storage is important – included? Pivotal is even small amt of storage, mtg peak load more easily achieved (justify more install) Excel energy example.	Material design for recyclability/ material science, or developing facilities for improvement

TECH AREA #2 – CONCENTRATED SOLAR POWER

Solar CSP provides the least energy of any renewable resource in California and has the lowest installed capacity.

- Current Baseline:
  - 2018 CA Capacity Factor: 23.4%
- Best in Class
  - Capacity Factor: >40%

- Cost Targets:

	FY 2017	FY 2018	FY 2019	2030 Target
Concentrating Solar Power	10 cents/kWh	n/a	8 cents/kWh	5 cents/kWh

SOLAR CSP - RECOMMENDED INITIATIVE#1

Initiative 3.1: Improve Dust Cleaning Systems for CSP Mirrors

Description and Characteristics	CSP systems have large areas of mirrors used to concentrate sunlight onto their receivers. These **mirrors need high reflectivity for good performance**, but they become soiled with wind-blown sand and dust. Mirror soiling can reduce plant energy production substantially (>50% loss) so frequent cleaning is necessary. Current cleaning methods are time consuming, expensive, prone to causing mirror breakage, and they can be water intensive.
Technology Baseline, Best in Class	Today's CSP systems use combinations of mechanized and manual cleaning techniques and even the best systems have difficulty **maintaining peak mirror performance**.
Impacts	**Better mirror reflectivity maintenance** would raise plant production by at least 10% to 15% over current practice and improved mechanized cleaning would also lower costs.
Metrics and/or Performance Indicators	Average mirror reflectivity and cost per unit area cleaned would provide comprehensive metrics.
Success Timeframe	Near term. This Initiative could produce highly useful results in a few years.

SOLAR CSP - RECOMMENDED INITIATIVE#2

Initiative 3.2: Research Corrosion Resistant Materials Able to Handle High Temperature Salts used for TES

Description and Characteristics	Achieving the DOE CSP endpoint cost target of 5 cents/kWh will require an **increase in system efficiency**. This is envisioned to involve power-block cycle conversion efficiencies of over 50% and getting those will require the high-temperature side of the cycle to exceed 700°C (1300°F). Such temperatures are higher than current system plumbing components and heat-transfer and heat-storage materials can handle.
Technology Baseline, Best in Class	Today's CSP system power cycles have high-temperature reservoirs at up to about 565°C (1050°F). This temperature is limited by both fluid stability and plumbing durability.
Impacts	Raising the upper temperature in the power cycle from 565°C to 700°C would increase its efficiency from about 30% to 50% with LCOE reduction in nearly inverse proportion.
Metrics and/or Performance Indicators	Useful metrics will be **material strength and corrosion rate versus temperature** as these will determine the amounts needed for salt containment and, therefore, the cost of the containers.
Success Timeframe	Medium term.

CSP INITIATIVE DISCUSSION

Q1 - Are these research initiatives the right ones for cost and technology breakthroughs for utility-scale renewable energy generation?

Q2 - What are he cost/performance targets for each technology that should be considered for California?

Q3 - Are there any gaps in these initiatives?

NOTES – CSP SOLAR

Right initiatives for cost and technology breakthroughs?		
For cleaning mirrors – could be of interest to combine with PV systems. Opportunity to combine PV and CSP cleaning.	Lot of work being done by DOE. Materials work is quite challenging, might be beyond what can be done. (better multi-tech)	Instead focus on things that support evaluation of CSP to gain experience curve, market factors
Mirror washing is good initiative, but there is wealth of int'l experience on this. CEC work should build upon tremendous int'l experience	Agree that DOE is doing a lot with materials CSP.	Market deployment is important (not good to compare PV to CSP, ignores that applications different). Hybrid may be better.
Cost and performance targets that should be considered?		
CSP does not have unique land use issues.	Is economic comparison to PV (integrated implicit energy storage)	
Gaps in these initiatives?		
Material research is time consuming, instead of designing material, less corrosion issues looking at working fluids. Attack problem from different angle.		

TECH AREA #3 – LAND-BASED WIND

Land-based wind provides the 2nd most energy of any renewable resource in California and has the 2nd most installed capacity.

- Current Baseline:
  - 2018 CA Capacity Factor: 27.1%
- Best in Class
  - Capacity Factor: ~50%

- Cost Targets:

	FY 2017	FY 2018	FY 2019	2030 Target
Land-Based Wind	5.5 cents/kWh (exceeded at 5.2)	5.4 cents/kWh	5 cents/kWh	3.1 cents/kWh

LAND-BASED WIND - RECOMMENDED INITIATIVE#1

Initiative 4.1: Onsite Assembly Improvement by Advancing Crane Technologies

Description and Characteristics	As California's WRAs are filled with wind turbines, new installations will have to occupy **more treacherous terrain at remote locations**. In addition, new wind turbines are typically much **larger with wider, longer, and heavier components** that in some cases are not possible to deploy due to the logistics of transportation to wind sites. **Onsite assembly and manufacturing allows wind components to be broken up and transported in more manageable pieces**. However, the ultimate assembly of wind components requires on-site cranes that also must journey to the job location and be capable of lifting and installing the large components. To reach the heights required for component installation on large turbines, **cranes with a larger weight capacity** that can attach to the turbine towers may be required. **Other crane designs** that are able to reach turbine locations and fit in small installation areas would also would serve the need for onsite manufacturing.
Technology Baseline, Best in Class	$80,000 a day for Crane rental. **Days to install** depends heavily on location, **number of pieces** to lift, and **size of turbine**.
Impacts	Proper crane selection and use can **lower the time it takes to assemble** wind turbines which will lower the cost of installation. Additionally, advanced cranes can enable assembly in areas where traditional wind installation is not possible by **removing barriers to transportation and onsite manufacturing**. This can unlock wind resources that are not currently accessible in California.
Metrics and/or Performance Indicators	**Installation Time**: Saves 1.5 to 2 Days ($120,000 to $160,000 on installation); Square Feet of Land Accessible for Wind Development; Weight Supported by Cranes; Blade and Tower Size that can be Installed

Success Timeframe

Near-Term

ent.

LAND-BASED WIND - RECOMMENDED INITIATIVE#2

Initiative 4.2: Deployment of Flexible Blades to Improve System Efficiency and Enable Access to Low-Wind Speed Areas

Description and Characteristics	On-land wind development in California is unlike any other state because of the age of the industry in the state. As a result of decades of operation, most high wind, attractive wind development areas are already taken by less efficient machines that have lower capacity factors and operate more variably than modern wind turbines. For land-based wind development in California to continue to grow, **low wind speed areas will have to be used** and ideally will generate electricity **with less variability than current wind installations** in the state. **Flexible blades are one early stage technology** that can decrease the variability of output from low-wind regions while increasing overall power output. When combined with longer blades and larger rotors, these flexible blade systems have the **ability to increase economical production from wind** in California. Flexible blades are also able to handle **variations in high wind speeds due to their ability to bend and twist passively to adapt to wind forces**. The first testing of passively adapting blades is underway in Colorado by a Germany company. There is room for R&D from U.S. counterparts as well as these designs being developed further.
Technology Baseline, Best in Class	35% **increase in converted energy** compared to rigid counterparts. **Increase in Capacity Factor** due to decreased downtime.
Impacts	Flexible and adaptable blades are able to operate in a **wider range of wind conditions** and dampen peak loads during times with high variable wind speeds. The use of these blades will also increase the **lifespan on blades** and **reduce maintenance costs**. Since flexible blades increase power production, they may also enable smaller capacity turbines to be more economical.
Metrics and/or Performance Indicators	Converted Energy: 35% increase; Capacity Factor; $/MWh; Lowest Wind Speed to Operate

Success Timeframe

Near-Term

LAND-BASED WIND INITIATIVE DISCUSSION

Q1 - Are these research initiatives the right ones for cost and technology breakthroughs for utility-scale renewable energy generation?

Q2 - What are he cost/performance targets for each technology that should be considered for California?

Q3 - Are there any gaps in these initiatives?

NOTES – LAND-BASED WIND

Right initiatives for cost and technology breakthroughs?		
There are related DOE/EPIC initiatives, why not radar mitigation/wildlife. Broadly longstanding permitting hurdles to wind (repower as well as greenfield development are substantial barriers), research initiatives associated with these barriers/informed by science.		
Cost and performance targets that should be considered?		
Gaps in these initiatives?		

TECH AREA #4 – OFFSHORE WIND

No offshore wind turbines are currently operating in the state.

- Current Baseline:
  - 2018 CA Capacity Factor: N/A
- Best in Class
  - Capacity Factor: >50%

- Cost Targets:

	FY 2017	FY 2018	FY 2019	Endpoint Target
Offshore Target	17.2 cents/kWh (target met)	16.2 cents/kWh	15.7 cents/kWh	14.9 cents/kWh by 2020 9.3 cents/kWh by 2030

OFFSHORE WIND - RECOMMENDED INITIATIVE#1

Initiative 5.1: Cost Reduction of Offshore Floating Systems with a Focus on Platform and Anchoring Systems

Description and Characteristics	Floating offshore wind turbines place a **horizontal wind turbine on a floating platform** that is anchored to the seabed with cables. These systems are necessary to **access wind resources in areas with water depths greater than 50 meters** due to the engineering complexity and cost associated with fixed bottom structures at those depths. California's coastline is best suited for these types of installations due to the water depth at high wind speed locations. Any **development of offshore wind resource in California above a small scale will require the development of floating platforms.** There is currently only a single offshore demonstration project in operation globally (Hywind in Scotland) with another funded (WindFloat in Portugal). The early-stage development of offshore wind technology means that the **understanding of platform and anchoring design** remains limited especially when considering factors such as water-depth and environmental concerns.
Associated Technology	Spar-Buoy Platform; Semi-Submersible Platform; Tension Leg Platform; Barge Platform; Multi-Turbine Platform; Hybrid Wind-Wave Platforms
Impacts	Early demonstrations of floating wind platforms will contribute **much needed data on performance, cost, and timeframes** to the global offshore wind industry. While local production is not necessary for this initiative, the installation of several offshore wind turbines will lead to California becoming one of the only states familiar with installation of offshore wind turbines giving the state rare institutional knowledge.
Metrics and/or Performance Indicators	$/MW Installation; LCOE; Capital Expenditures (CAPEX)
Success Timeframe	Long-Term (>5 Years)

OFFSHORE WIND - RECOMMENDED INITIATIVE#2

Initiative 5.2: Establishment of Local Manufacturing Capabilities for Offshore Tower Components

Description and Characteristics	**Offshore wind turbines are able to utilize much larger turbines and tower structures** as they are **not limited by any on-land transportation or construction constraints**. The larger blades and towers also allow offshore wind turbines to **reach higher wind resources to produce more energy.** However, California, currently lacks significant manufacturing capabilities throughout the wind turbine supply chain. With limited manufacturing facilities in the state and on the west coast as a whole, California will suffer from higher transportation costs and complex logistics associated with new land-based and offshore wind turbine installations. With the offshore wind industry still in a fledgling state, and floating offshore wind turbines at an even earlier stage of development, California has an opportunity to **become one of the first global manufacturing centers for offshore wind infrastructure**. Focusing on the manufacturing of offshore specific technologies like floating platforms, tower structures, and radar and wildlife detection systems will allow California to become a **global leader in offshore development**.
Impacts	Developing an offshore wind manufacturing industry in California will **decrease the costs of transportation of wind turbine components and create jobs** within the state. California is also positioned to become a leader across the Pacific Ocean as no floating structures and limited offshore deployment exists from the U.S. to Asia.
Metrics and/or Performance Indicators	$/MW **Installed Cost** of Offshore Turbines; **Average Transportation Distance** from Facility to Port
Success Timeframe	Long-term (>5 Years)

OFFSHORE WIND - RECOMMENDED INITIATIVE#3

Initiative 5.3: Ensuring that Port Infrastructure can Handle Large Wind Turbine Components

Description and Characteristics	Due to the large size of offshore wind turbines, large cranes and ample space are required at ports to pre-assemble and load turbine components onto installation vessels. Currently, **no port in California has the ability to load offshore turbine components** and few ports are able to accommodate the necessary equipment. **6 ports possible for improvements**: Humboldt Bay, San Francisco Bay, Hueneme, Long Beach, and San Diego. Locating and retrofitting a port so it is able to load an offshore wind turbine will be necessary to install any offshore wind turbines in California. Improvements to these ports could include **road/rail connections, higher capacity cranes, quayside space increases, and vessel availability**. Other improvements will be necessary based on the specific transportation and assembly requirements of the port.
Associated Technology Advancements	Fabrication & Construction Ports; Quick Reaction Ports; Assembly Ports
Impacts	This would enable entry of large components into the California market.
Metrics and/or Performance Indicators	**Average Distance** from Launching Port to California Installation Sites, **Days saved** with in-state Port Infrastructure, $/MW **Installed Cost**
Success Timeframe	Long-Term (>5 Years)

OFFSHORE WIND - RECOMMENDED INITIATIVE#4

Initiative 5.4: Improve Offshore Energy Interconnection through Development of Offshore High-Voltage Cables

Description and Characteristics	To connect offshore resources to the onshore grid, an **extensive cabling and interconnection systems is required**. Underwater cabling represents a very high cost for offshore systems, so **optimal design and** management of cables, interconnections, and substations is important to limit costs. Also, the type, structure, and location of cables should **minimize electrical losses** for the system. Currently, high-voltage alternating current (HVAC) cables are used most commonly to transmit power for the grid. For specific on-land and offshore transmission where there is a long transmission distance, High-voltage direct current (HVDC) transmission lines have been implemented.
Technology Baseline, Best in Class	High-voltage AC Cables
Impacts	HVDC cable infrastructure will **decrease power losses** and enable **more efficient connections** especially to resources located further from the shore. HVDC also require a smaller amount of material since they have smaller cross-section which limits cable cost and reduces the complexity of installation.
Metrics and/or Performance Indicators	**Lines Losses** (%); **Cost/Mile**; **Substation Cost**
Success Timeframe	Long-term (5+ Years)

OFFSHORE WIND INITIATIVE DISCUSSION

Q1 - Are these research initiatives the right ones for cost and technology breakthroughs for utility-scale renewable energy generation?

Q2 - What are he cost/performance targets for each technology that should be considered for California?

Q3 - Are there any gaps in these initiatives?

NOTES – OFFSHORE WIND

Right initiatives for cost and technology breakthroughs?		
4 initiatives are very appropriate. One to add for consideration is remote monitoring and maintained through drone inspection (onshore/offshore) Safety issue	Combination of wind and wave is higher than any individually, can address large part of storage issue to meet 100% target.	
Cost and performance targets that should be considered?		
Combining wind with ocean wave conversion farms, will allow improvement to infrastructure – reduce storage.	Siting is an issue, consider using artificial intelligence to determine.	
Gaps in these initiatives?		
Was wave tech not considered due to TRL, what is the TRL boundary? Answer – focused more on time horizon (1-3 years with high TRL 6 or 7), mid term (TRL 3-5 yrs, with TRL 4-6), long term (5 yrs, basic research). Advocating to include wave in long term consideration.	Lowering cost of energy through taking account of farm land synergies; breakthroughs could be made by considering large farm land systems. Combine with large farms already underway (10s to 100s of floaters needed), innovative mooring systems and touch technologies	There is nothing quite like a demonstration project – going and building (e.g. Europe growing so fast in wind). Not rocket science, generating enthusiasm in building demo project will be helpful.

TECH AREA #5 – BIOENERGY

Bioenergy facilities produce the 4th most energy in the state with the 5th highest amount of capacity.

- Current Baseline:
  - 2018 CA Capacity Factor: 51.0%
- Best in Class:
  - Capacity Factor: 60-70%
  - Conversion Efficiency: 75-80% (Biomass energy with CHP)
- Cost Targets:

	2014 (Low Range)	2014 (High Range)	2025 (Low Estimate)	2025 (High Estimate)
Stoker	6 cents/kWh	21 cents/kWh	5 cents/kWh	19 cents/kWh
Gasification	7 cents/kWh	23 cents/kWh	6 cents/kWh	20 cents/kWh
Anaerobic Digestion	6 cents/kWh	14 cents/kWh	5 cents/kWh	12 cents/kWh
Co-firing	4 cents/kWh	12 cents/kWh	4 cents/kWh	11 cents/kWh

BIOENEGY- RECOMMENDED INITIATIVE#1

Initiative 6.1: Improved Cleanup of Syngas Resulting from Gasification

Description and Characteristics	**Syngas from biomass gasification can be combusted to produce electricity or converted to chemical intermediates** (e.g., Fischer–Tropsch liquids, methanol, mixed alcohols, hydrogen). Producer gas from the gasification process must be cleaned into syngas to meet purity requirements for unique end-uses in internal combustion engines, gas turbines, fuel cells, biofuels, or chemical feedstocks. Raw biomass producer gas will likely contain **contaminants** (e.g., particulates, tar, alkali metals, and chlorine, nitrogen, sulfur compounds) depending on the biomass feedstock, design of gasifier (i.e., down-draft, up-draft, or fluidized bed) and operating temperatures. **Producer gas cleaning is a significant challenge to make a clean and viable syngas**. While advances have been made, gas contaminant cleanup remains expensive and can require multiple techniques, again depending on end use. Tar and ammonia removal are most problematic; **catalytic removal has been most promising** but still suffers from high cost, catalyst accessibility and fouling/deactivation. Catalyst application **requires solving scale-up issues** including temperature and pressure, impurities, fly ash, and catalyst destruction. Biomass gasification research has been ongoing for decades but it still expensive and unreliable compared to conventional combustion. **Research areas could include lower-temperature catalysts, biomass ash catalysts, reducing tar reformation, and scale-up**.
Technology Baseline, Best in Class	**Tar removal** during gasification (e.g., small particle feedstock) or post-gasification methods such as wet gas cleaning, dry gas cleaning, thermal cracking, catalytic cracking (e.g., nickel, non-nickel, alkali metal, acid catalysts, carbon-based); (2014) 23 **cent/kWh** for biomass gasification electricity production. **Ammonia removal efficiencies** for nickel catalysts 88-92% (high cost).
Impacts	Potential for **higher yields** and heating value of syngas; **higher purity**, **lower-cost** syngas with **greater market acceptance** for fuel and chemical production.
Metrics and/or Performance Indicators	**Lower-cost gasification**: (2025) 6 cents/kWh – 20 cents/kWh; 20% or more syngas **yield increase.**

Success Timeframe

Medium-term;

BIOENERGY - RECOMMENDED INITIATIVE#2

Initiative 6.2: Fund Thermal Hydrolysis Precursor to Anaerobic Digestion System Capable of Accepting Multiple Waste Streams

Description and Characteristics	Thermal hydrolysis pretreatment (THP) can be used as a precursor to Anaerobic Digestion (AD) to **increase biogas production** and **increase breakdown of organic material**.
Technology Baseline, Best in Class	Wet AD systems (high-moisture-content feedstock types) such as covered lagoon and complete mix digester; dry AD systems for relatively low-moisture-content feedstock (e.g., yard and green waste), including plug flow digesters. THP used successfully for wastewater treatment to reduce sludge.
Impacts	THP can potentially improve cake dewaterability, increase methane production, increase digester loading rates and produce bio-solids ready for land disposal. Potential cost reductions.
Metrics and/or Performance Indicators	Implementation of full scale thermo-pressure hydrolysis (TPH) shown to provide **higher anaerobic degradation efficienc**y; **increased biogas production** (+75-80%) achieved from waste activated sludge. **Enhanced degradation of organic matter** and improved cake's solids content from 25.2 to 32.7% TSS reduce sludge disposal costs about 25%. **Increased biogas production** (75-80%).
Associated Technology Advancements	Thermo-pressure hydrolysis, high pressure thermal hydrolysis. Studied primarily for wastewater pretreatment to reduce sludge. Studied for algae digestion.
Success Timeframe	Medium term; available for wastewater pretreatment, requires study and adaptation to biomass/dairy/diverted organic waste AD operations (common in CA).

BIOENERGY INITIATIVE DISCUSSION

Q1 - Are these research initiatives the right ones for cost and technology breakthroughs for utility-scale renewable energy generation?

Q2 - What are he cost/performance targets for each technology that should be considered for California?

Q3 - Are there any gaps in these initiatives?

NOTES – BIOENERGY

Right initiatives for cost and technology breakthroughs?		
Syngas cleanup important – can it be extended to pyrolysis activity. Recommended initiatives do not address torrefaction pyrolysis at lower temps. Can it be expanded to include both (to include solid fuels from pyrolysis)	Initiative # 1, syngas cleanup, is similar to EPIC III initiative (similar ones may be eliminated)	Syngas clean up is important, shouldn't limit to gasification (there are a number of techs), language should be open enough. THP is pretreatment for feedstock for AD, but can be other processes. Careful not to limit to just AD.
Biochar should be considered.		
Cost and performance targets that should be considered?		
Gaps in these initiatives?		
Report points to previous assessments (UC Davis), 2013. A lot of changes recently, might be worthwhile to do assessment for feedstock logistics from forestry and ag. Ag impacted by closers of plants, and incentivized forest feedstock.	Focus on microbial fuel cells to treat wastewater and treat directly from Microbial activity.	

TECH AREA #6 – GEOTHERMAL

Geothermal power produces the 3rd most energy in the state with the 3rd highest amount of capacity.

- Current Baseline:
  - 2018 CA Capacity Factor: 48.2%
- Best in Class:
  - Capacity Factor: Up to 70%

- Cost Targets:

	FY 2017	FY 2018	FY 2019	Endpoint Target
Geothermal Systems	22 cents/kWh (target met)	21.8 cents/kWh	21.7 cents/kWh	6 cents/kWh by 2030

GEOTHERMAL- RECOMMENDED INITIATIVE#1

Initiative 7.1: Improving Materials to Combat Corrosion from Geothermal Brines

Description and Characteristics	The **high salinity of geothermal brines**, especially in the Salton Sea region of California, **degrades metal used throughout the power production process**. As a result, **expensive titanium-alloys** are often used to prevent corrosion and reduce maintenance costs. New materials made from base metals such as nickel have been tested but still lack the durability of titanium-alloys. However, further advancement and testing of metal alloys may reveal lower cost and more corrosion-resistant materials.
Associated Technology Advancements	Titanium-Alloys and other corrosion-resistant materials
Success Timeframe	Long-term

GEOTHERMAL - RECOMMENDED INITIATIVE#2

Initiative 7.2: Explore Electricity Potential from Idle Oil and Gas Wells through the Use of Downhole Heat Exchangers

Description and Characteristics	Oil and gas wells are plentiful in the state of California with around 30,000 of those wells being abandoned. These wells present an opportunity to extract geothermal energy by using heat exchangers that are placed in the drilled wells. Extracting geothermal energy in this way avoids the extremely high drilling costs necessary for the majority of new projects. Typical **downhole heat exchangers are able to extract both thermal and electrical energy**. They are more efficient at generating electrical energy is deeper wells however. The average capacity of a downhole heat exchanger is not high enough to generate utility scale power. However, the tight coupling of oil wells should allow for **combination of a number of downhole heat exchanger units** to provide enough energy to be put into the grid.
Associated Technology Advancements	Borehole Heat Exchangers
Success Timeframe	Long-term

GEOTHERMAL INITIATIVE DISCUSSION

Q1 - Are these research initiatives the right ones for cost and technology breakthroughs for utility-scale renewable energy generation?

Q2 - What are he cost/performance targets for each technology that should be considered for California?

Q3 - Are there any gaps in these initiatives?

NOTES – GEOTHERMAL

Right initiatives for cost and technology breakthroughs?		
High drilling cost and high flow rates are barriers, initiatives focused on these issues important. $40MM DOE project on drilling in UT as example – synergy with that project.	Importance of field testing initiatives, step out to areas adjacent or in geothermal fields, to promote research for geothermal. Access to transmission important, more rapidly deployed.	Additional comments submitted via online comment form.
Cost and performance targets that should be considered?		
Gaps in these initiatives?		

TECH AREA #7 – SMALL HYDRO

Small hydropower resources produce the 5th most energy in the state with the 4th highest amount of capacity.

- Current Baseline:
  - 2018 CA Capacity Factor: 27.6%
- Best in Class:
  - Capacity Factor: ~50%

- Cost Targets:

	FY 2017	FY 2018	FY 2019	Endpoint Target
Small Hydro (streams)	11.5 cents/kWh (target met)	11.4 cents/kWh	11.15 cents/kWh	10.9 cents/kWh by 2020 8.9 cents/kWh by 2030

SMALL HYDRO- RECOMMENDED INITIATIVE#1

Initiative 8.1: Developing Parts and Systems to Standardize Hydropower Development

Description and Characteristics	Developing small hydro systems requires site-specific engineering, which raises costs. Developing standardized components and methods can both decrease these costs and enhance system feasibility. **Standardized components that can be reused in a variety of flows and sites** can allow an economy of scale to develop, further decreasing costs.
Technology Baseline, Best in Class	TBD
Impacts	Standardized turbine components can make the manufacturing, deployment, and maintenance of in-conduit systems cheaper and faster by developing an economy of scale for the industry.
Metrics and/or Performance Indicators	This initiative should **decrease system costs**, which in turn should **enable more system deployment.**
Associated Technology Advancements	Standardized turbine components can incorporate new technologies to further drive down turbine costs. Composite materials and inflatable weirs offer potential methods of standardization for turbines. Reusable versions of these materials can also reduce costs.
Success Timeframe	Near Term

SMALL HYDRO- RECOMMENDED INITIATIVE#2

Initiative 8.2: Fund Deployment of Small Hydro Systems that Use Permanent Magnet Generators

Description and Characteristics	Permanent magnet generators (PMGs) can offer some of the same benefits that they offer wind turbines by allowing the small hydropower units to generate power at variable speeds. PMGs are well adapted to handle the variations that can be expected in California due to sporadic rainfall and tight water supplies. PMGs will be able to make small hydropower sites economic if there are reductions in cost for the technology. Deployments of PMGs will also have to be adaptable to many different small hydropower sites to avoid issues with installation.
Associated Technology Advancements	Permanent Magnet Generators
Success Timeframe	Mid-term (3-5 Years)

SMALL HYDRO INITIATIVE DISCUSSION

Q1 - Are these research initiatives the right ones for cost and technology breakthroughs for utility-scale renewable energy generation?

Q2 - What are he cost/performance targets for each technology that should be considered for California?

Q3 - Are there any gaps in these initiatives?

NOTES – SMALL HYDRO

Right initiatives for cost and technology breakthroughs?		
Two research areas would add little value to development for small hydro. Due to 401 certification.	Most potential – conduits for hydro, man made infrastructure. Connect to grid and distribution system, is where to focus. Heavily governed by Rule 21. No credit for grid benefits that it offers. Barriers to entry ripe for research – incentive programs or policy that would allow for co-op, IOU etc. which may defer grid upgrades. Configured based on capacity factors that seem low.	Like biomass, small hydro provides grid benefit, how to balance with grid investments. Has to survive on cash flow. Policy changes for this to flourish
Small modular incentives (CEC funded) already underway.	How can small distributed hydro improve CA's grid?	
Gaps in these initiatives?		
Every site is new for hydro. No incentive to take panel, lack of clarity on IOUs, no incentive for non-std panel thru nat'l certification process. Std to fast track to interconnection.	Configure small hydro to be more connected, standardization	

TECH AREA #8 – GRID INTEGRATION

Grid Integration Technologies and Strategies can be grouped into four categories:

- Transmission and Distribution Infrastructure
- Devices, Measurement, and System Controls
- Design, Modeling, and Resource Planning
- Resilience

California requires expansion of grid infrastructure either in the form of retrofits or new installations.

GRID INTEGRATION - RECOMMENDED INITIATIVE#1

Initiative 9.1: Support Continued Advancement of High-Temperature Low-Sag Conductors

Description and Characteristics	**Transmission lines in California are operating either near, at, or above their design rating,** limiting the amount of electricity which can flow along them. Utilities still primarily use traditional aluminum-conductor steel-reinforced (ACSR) cable technology for their transmission lines. New developments in conductors have led to commercialization of several types of high-temperature low-sag (HTLS) conductors. **HTLS conductors use different materials than ACSR conductors.** Typically some type of aluminum is used as the conductor and the interior features a material with high tensile strength. To eliminate issues with heat and sag that result from the use of a steel core in ACSR conductors, the core is typically replaced with a different metals or composite materials. These new conductors can carry **2.5 times the amount of current of ACSR conductors** of the same size and are able to handle continuous temperatures of 150-210°C compared to 100°C for ACSR. The lower coefficient of thermal expansion for HTLS conductors reduces sag even as more current is transported over the lines. HTLS conductors have been on the market over the past decade, but still are not deployed widely due to their higher cost than ACSR conductors and the long lifetime of conductor cables.
Impacts	Replacing existing conductors in California with HTLS conductors can **increase line capacity** on existing infrastructure without the need for new power towers and other expensive infrastructure. The reduced sag on power lines will **reduce the risk of wildfires** due to powerlines. Further **decreases in HTLS conductor costs over time will decrease the payback** period of these conductors and make them an even more attractive alternative to ACSR wires. HTLS conductors also reduce line losses which increases the overall efficiency of the grid.
Metrics and/or Performance Indicators	MW/Power Line; Percent of Line Losses; Sag Distance of Power Lines; Number of Wildfire caused by Power Lines
Associated Technology Advancements	Gap-type Thermal Aluminum Conductor Steel Reinforced (GTACSR); Super Thermal Aluminum Conductor Invar Reinforce (ZTACIR); Aluminum Conductor Steel Supported (ACSS); Aluminum Conductor Composite Reinforced (ACCR)
Success Timeframe	Mid Term

Initiative 9.2: Advancement of Smart Inverters to Improve Communication and Cybersecurity

Description and Characteristics	The electricity grid is transitioning to a system with multiple points of generation and consumption which integrates variable energy systems, large scale energy storage, and net metering enabling the development of thousands of distributed energy systems. In order to maintain grid stability, **grid operators must be able to access data in real-time and communicate with multiple inverters on the grid**. To integrate the power from many renewable sources onto the grid, the electricity produced by renewables must be passed through an inverter to match the voltage and frequency of power on the grid. **Smart inverters can allow data to be transferred faster which allows the grid to monitor early warnings of grid events and behavior, identify failing equipment, and develop improved system models among other capabilities**. California is already transitioning away from traditional (non-smart) inverters due to the implementation of Rule 21. However, not all smart inverters that fulfill Rule 21's requirements have the level of responsive and security available on the market or possible with further development. To increase the speed that data is available from smart inverters, the **devices must be internet connected and able to access grid monitoring and control systems directly**. However, the increased amount of data and frequency of data transfer requires careful management and standards of practice to ensure security. **Cyberattacks** in particular have become a point of focus for new smart inverter technologies.
Impacts	Inverters will be able to transfer data and be remotely controlled with **limited risk of cyberattack**. Contingencies will be required in case a cyberattack does occur. The advancement of smart inverters at the grid will require an accepted standard for data transfer as well. An increase in smart inverters on the grid will enable more efficient transmission and distribution of electricity and will improve integration of renewable energy sources. The quicker and safer data can be transferred, the more efficient the system can be
Metrics and/ Indicators	MWh of Curtailed Renewable Energy, MWh of Energy Losses due to Interconnection, Cyberattacks Reported per Year
Associated Advancements	Synchrophasor technology can collect 30 to 60 samples per second to provide grid performance Encryption of transferred data; Virtual Oscillator Control (VOC).
Success Timeframe	Near-Term (1-3 Years)

GRID INTEGRATION INITIATIVE DISCUSSION

Q1 - Are these research initiatives the right ones for cost and technology breakthroughs for utility-scale renewable energy generation?

Q2 - What are he cost/performance targets for each technology that should be considered for California?

Q3 - Are there any gaps in these initiatives?

NOTES – GRID INTEGRATION

Right initiatives for cost and technology breakthroughs?		
Suggest adding initiative focusing on demonstrating long duration storage.	Suggest focus on transactive energy systems. Potential for integrating renewables and improving load factor on the grid	
Grid integration services and transmission services		
Cost and performance targets that should be considered?		
Gaps in these initiatives?		

TECH AREA #9 – ENERGY STORAGE

Current energy storage capacity in California is at 4.3 GW with over 95% of that capacity supplied by Pumped-Storage Hydropower (PSH)

- Current Baseline:
  - Round-Trip Efficiency: 60-80%
- Best in Class:
  - Round-trip Efficiency: >80%

- Cost Targets:

	FY 2017	FY 2018	FY 2019
Grid-scale (>1 MW) aqueous soluble organic electrolyte (redox flow battery system)	$350/kWh for a 4-hour aqueous soluble organic flow system	$225/kWh for a 4-hour aqueous soluble organic flow system; projected 1 MW/4 MWh system operating at 150 mA/cm^2	By the end of FY 2025, the cost of a prototype redox flow battery system will be $100/kWh

ENERGY STORAGE - RECOMMENDED INITIATIVE#1

Initiative 10.1: Support Research into Long Duration Energy Storage Systems (8-hour or greater)

Description and Characteristics	**Energy storage systems are limited by the amount of time they can store and discharge energy**. Most storage systems have storage capabilities which last from minutes to a few hours. Longer duration storage systems are necessary to mitigate the future effects of increased penetration in variable renewable resources. Long duration storage time frames need to **increase to lengths of many hours to days in order to support additional renewable resources**. Longer duration storage could help **reduce renewable generation curtailment, reduce natural gas ramping requirements to meet evening peak demand, and even shift excess renewable generatio**n to days and/or seasons that have less generation.
Technology Baseline, Best in Class	Lithium-ion batteries – minutes to a few hours; flow batteries – up to about 8 hours; fly wheels – minutes, usually less than an hour; pumped hydro – hours; thermal storage technologies – up to 8 hours
Impacts	Long duration energy storage will support continued renewable energy deployment in California, reduce renewable curtailment, and reduce evening natural gas plan ramping.
Metrics and/or Performance Indicators	**Duration** – typically measured in minutes to a few hours. Duration should increase beyond 8 hours into multiple days.
Associated Technology Advancements	Flywheels, Battery Improvements, Small-Scale Pumped Hydro Storage, Thermal Energy Storage
Success Timeframe	Long Term: 5 years +

ENERGY STORAGE - RECOMMENDED INITIATIVE#2

Initiative 10.2: Fund Recycling Programs for Energy Storage Systems (Particularly Lithium-Ion Batteries)

Description and Characteristics	In the coming decades there is expected to be terawatt hours of used electric vehicle (EV) batteries in addition to the gigawatt hours of stationary battery storage, nearly all of which are currently lithium-ion technologies. However, there are currently **no lithium-ion battery recycling programs in California**. Without recycling programs, these batteries will either be thrown away or sent out of state or out of country for repurposing or recycling, and potentially pose a serious environmental hazard if recycling is not done properly. **Sending used batteries out of California is a massive lost opportunity for the state** as keeping the battery materials in-state could create new markets for recycled battery materials and components and spur California's battery manufacturing industry.
Technology Baseline, Best in Class	Less than half of lithium-ion batteries are currently recycled. Those that are recycled are typically sent to Europe or China where batteries are incinerated to extract materials.
Impacts	Reduce environmental impacts of discarded or improperly dismantled batteries; economic benefit through job and market creation and potentially reduced costs of batteries; creation of battery manufacturing industry.
Metrics and/or Performance Indicators	**MW/MWh capacity of recycled/reused batteries**; number and **percentage of recycled batteries**, **number of jobs created**.
Associated Technology Advancements	Streamlined recycling processes; metal and material extraction processes; battery manufacturing from recycled materials.
Success Timeframe	Mid-term/long-term

ENERGY STORAGE INITIATIVE DISCUSSION

Q1 - Are these research initiatives the right ones for cost and technology breakthroughs for utility-scale renewable energy generation?

Q2 - What are he cost/performance targets for each technology that should be considered for California?

Q3 - Are there any gaps in these initiatives?

NOTES – ENERGY STORAGE

Right initiatives for cost and technology breakthroughs?		
Long duration energy storage – important as we deploy renewables. Should include investigating hydrogen energy storage, and renewable nat. gas storage.	Need focus on improving round trip efficiency and reducing cost of flow batteries	Agree with these initiatives being high priority.
Consider managed electrified fleet vehicle charging as an asset, different form of DER.		
Cost and performance targets that should be considered?		
Success timeframe – there are techs that can demonstrate success earlier than that.		
Gaps in these initiatives?		
Missing hydrogen energy storage, as mature or more mature than others listed	Hydrogen important for future research, Europe, hydrogen in to methane, also electrolyzers (from renewable sources), further analysis or assessment of how these are going in Europe	

WEBINAR CLOSING

(accessible on the Energy Commission [Research Idea Exchange docket](#))

Written comments will be received by the Energy Commission through July 12, 2019.

Now:

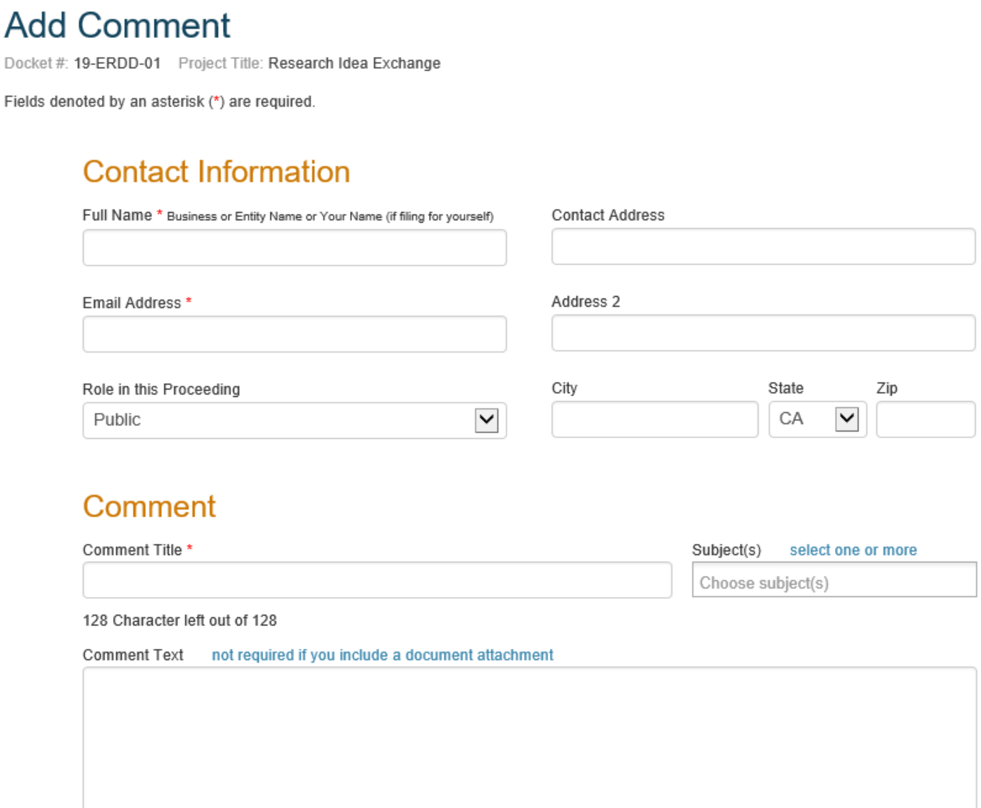
- Technical Assessment
- Preliminary Report

Next Week:

- June 28 Public Webinar Slides

Future Date:

- Roadmap Report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