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California Energy Commission

STAFF REPORT

Electric Program Investment Charge: Proposed 2018 – 2020 Triennial Investment Plan

California Energy Commission

Edmund G. Brown Jr., Governor

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California Energy Commission

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ABSTRACT

The California Energy Commission has prepared this proposed triennial investment plan (2018-2020) for the Electric Program Investment Charge Program in response to the California Public Utilities Commission Decision 12-05-037 (modified). This proposed plan is consistent with California Public Utilities Commission Decision 13-11-025 and continues implementing the requirements established by Senate Bill 96 (Committee on Budget and Fiscal Review, Statutes of 2013). The California Public Utilities Commission Decision 12-05-037 established the Electric Program Investment Charge Program to fund electric public interest investments to benefit the electricity ratepayers of Pacific Gas and Electric Company, Southern California Edison Company and San Diego Gas & Electric Company.

In Decision 12-05-037, the California Public Utilities Commission approved a total of $162 million annually beginning January 1, 2013, and continuing through December 31, 2020, unless otherwise ordered or adjusted in the future by the California Public Utilities Commission. The California Public Utilities Commission shall adjust the total collection amount on January 1, 2015, and January 1, 2018, commensurate with the average change in the Consumer Price Index, as specified. The California Energy Commission is administering 80 percent of the approved Electric Program Investment Charge funds.

Staff developed this third proposed Electric Program Investment Charge Investment Plan through an open process that involved public workshops and consultation with key stakeholder groups. Input from these stakeholders is reflected in the recommended funding initiatives.

The California Public Utilities Commission will conduct a formal proceeding, starting in May 2017, to consider this proposed plan with anticipated adoption in December 2017. The investor-owned utilities are developing their own investment plans to fund technology demonstration and deployment initiatives. The California Energy Commission is working to coordinate its Electric Program Investment Charge Investment Plan with the plans of the investor-owned utilities.

Keywords: California Energy Commission, Electricity Program Investment Charge, applied research and development, technology demonstration and deployment, market facilitation, clean energy technologies, renewable energy, guiding principles, electricity value chain, energy innovation pipeline, energy efficiency, smart grid, clean generation

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TABLE OF CONTENTS

Page

LIST OF FIGURES

Page

LIST OF TABLES

EXECUTIVE SUMMARY

California, a state with a diverse, dynamic and creative population, has pushed the world's sixth largest economy to the forefront of environmental, economic, technological, social and cultural development. The electricity system has served as the backbone for much of this development, providing vital contributions to California, its economy and its diverse people. However, this system must evolve to meet the demands of the 21st century.

Over the past decade, California has made significant progress towards transforming its electricity system to meet these demands. "Greenhouse gas emissions have declined over the past decade" even as California's economy has grown.[1] Renewable generation accounts for 27 percent of electricity supply, driven in large part by the rapidly declining cost of solar photovoltaic and wind generation technologies. These advancements have demonstrated the state's ability to transform its electricity system in a relatively short time frame and, in the process, provide California's leaders with the confidence to adopt even farther-reaching energy and climate goals.

Despite this progress, today's energy technologies are unlikely to be sufficient to drive the scale of change needed to avoid the most serious impacts of climate change. The pace of decarbonization in the electricity sector will need to ramp up considerably to meet the state's climate goals.

Electricity generation is the second largest source of greenhouse gases, contributing about 20 percent of the state's overall emissions. Even with significant energy efficiency improvements, overall electricity consumption is expected to increase over the next few decades partly because of increased demand from climate change impacts.

Solar photovoltaic (PV) generation has become the electric generation technology option of choice but high-penetrations of PV are creating new technical challenges from intermittency and unpredictability. Such challenges impact power quality and reliability and must be overcome to help the state meet its long-term greenhouse gas (GHG) emission reduction goals.

The challenges ahead will require transformational technologies, combined with innovative deployment strategies and informed decision-making to spur mass adoption of clean energy solutions and avoid potential unintended consequences – for example, incurring expensive sunk costs from stranded infrastructure – that may hinder the state's long-term ability to meet its energy and climate goals. With the federal landscape changing, California's leadership will be needed now more than ever.

1 California Energy Commission – Tracking Progress, http://www.energy.ca.gov/renewables/tracking_progress/documents/Greenhouse_Gas_Emissions_Reductions.pdf

A Decade of Progress: Accelerating the Evolution of California's Electricity System

The landscape of California's electricity sector has changed dramatically in the past 10 years. California has seen significant improvement in every metric used to measure progress toward transforming its electricity sector and building a clean energy economy. Renewable generation, driven by significant cost reduction in solar and wind, has increased from just over 10 percent of electricity production in 2006 to 27 percent in 2016, putting it ahead of schedule to meet the state's Renewables Portfolio Standard (RPS) for 2020.

Energy efficiency indicators have also shown significant progress over the past decade. According to the 2016 Green California Index, per capita energy consumption from 1993 to 2005 remained relatively constant, hovering around a level roughly 15 percent lower than in 1970. "In 2013, per capita energy consumption was down 27.5 percent in California compared to 1970."[2]

Recent trends in GHG emission per gross domestic product indicate the state succeeded in decoupling economic growth from climate pollution. Electricity sector emissions in 2014 were about 20 percent below 1990 levels, this exceeds the Global Warming Solutions Act of 2006 goal to reduce GHG emissions to 1990 levels by 2020.[3]

BUILDING A SOLAR LEADER THROUGH CALIFORNIA POLICY SUPPORT

In the 2000s, California's solar-friendly policies were starting to stimulate market adoption for solar photovoltaic systems. This growth in demand was creating a need for three things: cheaper and more-efficient solar cells, improved aesthetics of rooftop solar PV, and systems to integrate the various solar installation tasks and components into one cost-effective procedure.

Throughout the 1990s and 2000s, the Energy Commission supported the development of multiple products from a California company called Powerlight. These products helped overcome the early aesthetic barriers to solar energy and streamline the installation of both rooftop and utility-scale PV systems. During this time, SunPower, another California solar company and Energy Commission recipient, was establishing itself as a leader in solar cell efficiency and was Powerlight's largest solar cell supplier. In 2007, the two companies merged under SunPower to become a vertically integrated solar company.

Since then, SunPower has become a global leader in solar energy. Its products have helped reduce the cost of California's solar policies and incentive programs, which in turn have helped SunPower become an industry leader in clean energy.

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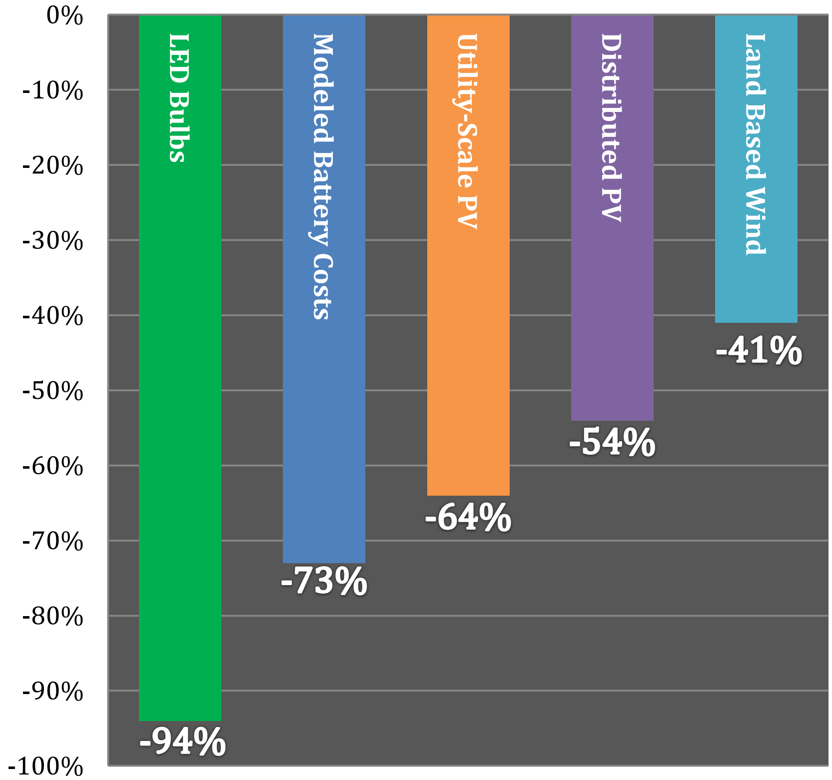
2 Next 10, 2016 *California Green Innovation Index.* 2016
3 California Energy Commission – Tracking Progress, http://www.energy.ca.gov/renewables/tracking_progress/documents/Greenhouse_Gas_Emissions_Reductions.pdf

California's clean energy economy has also expanded in the past decade. In 2006 total investments in California clean technology companies were less than $2 billion. By 2015, the amount of investment had increased fivefold to just under $10 billion. Clean technology patents, another indicator of the clean energy economy, has also increased significantly in the past decade. In 2006, the number of new patent registrations for clean technologies in California was roughly 1,000. By 2015, the number of newly registered clean technology patents in California has grown to more than 4,000 annually, making up almost a quarter of all clean technology patents for the country that year.[4]

Much of the progress of the past decade can be attributed to the various policy instruments California's leaders have adopted to accelerate the development and deployment of clean energy technologies. "Market pull" policies such as the California Solar Initiative and the RPS have helped create the necessary market signals for clean energy technologies, while "technology push" policies such as the Public Interest Energy Research and EPIC programs advanced research, development, and demonstration to drive further technical and cost performance of clean energy technologies.

Figure 1 Indexed Cost Reductions Since 2008



Source: DOE Report, Revolution Now, The Future Arrives for Five Clean Energy Technologies - 2016 Update

"BOTH OF THESE KINDS OF TOOLS [MARKET PULL AND TECHNOLOGY PUSH POLICIES] CAN BE EFFECTIVE, BUT THE MOST EFFECTIVE POLICY PORTFOLIO BALANCES A COMBINATION OF THESE POLICIES."[5]

4 Next 10, *2016 California Green Innovation Index*, 2016.

5 Narayanamurti, Venkatesh, Laura Diaz Anadon, Gabe Chan, and Amitai Y. Bin-Nun. "Securing America's Future: Realizing the Potential of the DOE National Laboratories." Testimony to United States Senate, Senate Appropriations Subcommittee on Energy & Water Development. Washington, D.C, October 28, 2015

New Challenges: Getting to 2030 and Beyond

California's pursuit of a low-carbon future will hit a critical milestone in 2030. The Clean Energy and Pollution Reduction Act (Senate Bill 350, de Leon, Chapter 547, Statutes of 2015) set targets for energy efficiency and renewable generation for 2030. In 2016, the California Global Warming Solutions Act (Assembly Bill 32, Núñez, Chapter 488, Statutes of 2016) was updated to require GHG reductions of 40 percent below 1990 levels by 2030.

Despite the electricity sector's gains over the past decade, the pace of progress needs to increase exponentially. The demands of a growing population and economy, combined with increased electricity use due to climate change impacts, will challenge the electricity sector's ability to meet these goals. Further electrification of the transportation and natural gas sector needed to meet GHG reduction targets will compound this challenge.

Electricity Demand

"Even the most optimistic scenarios about the penetration of energy efficiency suggest considerable increases in electricity demand with the electrification of energy services."[6,7] The greatest opportunities for energy savings are in traditionally hard-to-reach sectors such as existing buildings and industrial plants. Without policy changes, current technology options in most cases do not meet acceptable payback periods or customer performance requirements necessary to drive large-scale adoption of energy efficiency upgrades. Other distributed energy resources, including rooftop solar PV and onsite battery storage,

Top 10 GHG Reduction Deployment and Research Needs

During the 2016 EPIC Symposium, Energy + Environmental Economics presented the top 10 priorities for low-carbon energy transformations in California. EPIC addresses seven of the items on the list, displayed in bold below:

10. Natural and Working Lands

9. Reducing Vehicle Miles Traveled

8. Commercialization of Low-Carbon Gases: Biogas, Renewable Hydrogen, Low-Carbon Methane

7. Sustainable Freight and Trucking – Commercialization of Advanced, Sustainable Biofuels and Electrification Options

6. Industrial Emissions Reductions

5. Heat Pump Market Experience and Deployment

4. Reducing Non-Energy GHGs and Short-Lived Climate Pollutants

3. Renewable Procurement and Integration

2. Deep Energy Efficiency in Buildings and Retrofits

1. Deployment of Electric Vehicles

6 Wei, M., Nelson, J.H., Greenblatt, et al., (2013). "Deep carbon reductions in California require electrification and integration across economic sectors." Environmental Research Letters. 2013; 8:014038.
7 Wei, Max; Jeffery Greenblatt; Sally Donovan; et al., (2014). Scenarios for Meeting California's 2050 Climate Goals.

have the potential to significantly reduce customer energy use and; when paired with advanced communication and control technologies, can provide benefits beyond energy bill savings. However, high upfront costs and uncertain payback periods remain a barrier for the mainstream customer markets.

Renewable Generation

On the supply side, planning and operating the electricity system will become more challenging. Solar PV has become the technology of choice for utility-scale renewable generation and is projected to play a major role in meeting California's RPS. However, the marginal value of new solar PV capacity is expected to decline once it reaches 20 percent of annual electricity demand unless low-carbon solutions that provide system flexibility can be cost-effectively deployed.

Climate change impacts and electrification are expected to impact not just electricity demand, but electricity supply as well. Higher temperatures resulting from climate change will lower the performance of both renewable and conventional generation and limit the availability of hydropower in hot summer months. Electrification of space heating could also change the diurnal and annual electricity loads, even creating the possibility of a new wintertime peak demand. This, in turn, would change the preferred portfolio of electricity generation options to ones that can best meet the new load profiles. For example, wind might become more attractive compared to solar generation to meet new load profiles.

Climate Change Impacts

In addition to the impacts discussed above, climate change is also expected to exacerbate the frequency and intensity of wildfires which, as in the recent past, would affect the operation of both transmission and distribution lines resulting in grid disruption unless adequate adaptation measures are implemented. Climate change will also increase the risks of droughts, potentially creating operational problems for power plants using water as their cooling agent. More than 102 million drought-stressed trees have died due to bark beetle infestation since 2010. Hotter temperatures will not only make air conditioning units operate harder, but it will also induce the penetration of space cooling in areas that traditionally have not needed this energy service.

Figure 2 Wildfires Can Have Significant Impacts on California's Grid

Source: California Energy Commission, Energy Innovation Showcase

Financing Innovations

Many of the challenges ahead will depend on the development and scale-up of new energy innovations. The availability of private venture capital (VC) has played a critical role in successfully bringing disruptive innovations to market in other technology sectors, such as the information technology and biomedical sectors. The same level and pace of innovation developments seen in those industries are now needed in the clean energy sector. However, clean energy technology companies developing new materials, hardware, chemicals, or processes are poorly suited for VC investment because they require significant capital and have long development timelines. VC firms tend to work on a three-to-five year scale, but the average time from founding to initial public offering for clean-tech startups was 8.3 years.[8] Even if a VC firm could afford to wait that long, the chances of a return on investment was low. From 2006 to 2011, only 5 percent of early-stage clean energy technology firms returned profits to their investors through acquisition or an initial public offering, as opposed to 18 percent of early-stage software firms started during the same period.[9]

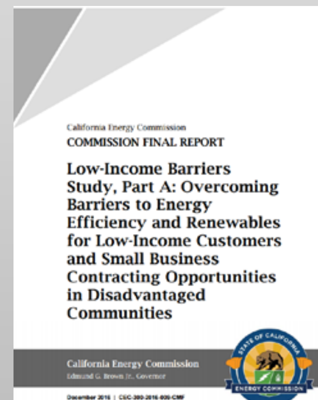
The high capital requirements, long development timelines, and low chance of returns, combined with the financial recession in 2008, contributed to a steep drop in private sector investments in clean energy technology over the last 10 years. In 2008, U.S. VC investments in clean energy technology exceeded $5 billion, but dropped to $2 billion by 2013, and have remained roughly constant since.[10]

Disadvantaged Communities and Low-Income Customers

As California continues to transition to a low-carbon energy future, the state must take steps to ensure the benefits are equitably shared, especially by those in the most vulnerable communities. In 2016, the Energy Commission adopted the Low-Income Barriers Study to explore barriers to and opportunities for expanding clean energy deployment in disadvantaged communities. The study identified several barriers unique to disadvantaged communities. According to the study, “some barriers are structural, inherent to the conditions of poverty in California. These barriers may be mitigated but are difficult to eradicate. Other barriers stem from policy and program decisions, and these may be overcome through new policy development or program refinement.”[11]

Low-Income Barriers Study

In December 2016, the Energy Commission released a report that explores the barriers to and opportunities for expanding low-income customers’ access to energy-efficiency, weatherization, and renewable energy investments. It also examines barriers and opportunities related to contracting with small businesses located in disadvantaged communities.



8 Eilperin, Juliet. “Why the Clean Tech Boom Went Bust.” Wired. 2012. https://www.wired.com/2012/01/ff_solyndra/

9 Department of Energy, *Quadrennial Energy Review Transforming the Nation’s Electricity System: The Second Installment of the QER.* 2017 https://www.energy.gov/sites/prod/files/2017/02/f34/Quadrennial%20Energy%20Review--Second%20Installment%20%28Full%20Report%29.pdf

10 Gaddy, Benjamin, Varun Sivaram, Francis, O’Sullivin 2016. *Venture Capital and Cleantech: The Wrong Model for Clean Energy Innovation* https://energy.mit.edu/wp-content/uploads/2016/07/MITEI-WP-2016-06.pdf

11 Scavo, Jordan, Suzanne Korosec, Esteban Guerrero, Bill Pennington, and Pamela Doughman. 2016. Low-Income Barriers Study, Part A: Overcoming Barriers to Energy Efficiency and Renewables for Low-income customers and Small Business Contracting Opportunities in Disadvantaged Communities. California Energy Commission. Publication Number: CEC-300-2016-009-CMF

Preparing for the Next Stage of the Electricity System's Transformation

To address the challenges ahead, California's leaders are devising and implementing innovative policies that will lay the foundation for the next phase of the transformation of the electricity system. Most of these policies aim to create increased market demand for low-carbon energy technologies and drive further economies of scale. The Electric Program Investment Charge (EPIC) program fills a critical gap, providing the "technology push" policy to complement these "market pull" policies.

A Plan for Distributed Energy Resources

In 2016, the California Public Utilities Commission (CPUC) released the Distributed Energy Resources (DER) Action Plan to "serve as a roadmap for decision-makers, staff and stakeholders working in support of California's DER future." The DER Action Plan provides a vision and action to "develop the market opportunities and remove unnecessary barriers to unleash the full value that DERs can provide."

The Energy Commission has awarded a large portfolio of projects supporting the DER Action Plan, many of these projects are aimed at improving the communication and control technologies and data analytics needed to optimize the benefits of DERs. Other projects are demonstrating different DER technology packages to prove the related value and resolve the potential technical, business and regulatory risks to customers and policy makers.

A New Role for Automated Demand Response

California's energy policies envision a future electricity system significantly more decentralized and decarbonized than the one that developed a century earlier. Driving this transition are distributed energy resources (DER). According to the U.S. Department of Energy the infrastructure needed to enable DER includes technologies that enable Demand Response.

In the years following the energy crisis of 2001, the Energy Commission established the Demand Response Research Center to explore ways to automate demand response and expand its use for lowering peak demand. This included the development of the open standard "OpenADR™. The open standard has allowed automated demand response to scale quickly and cheaply. More than 120 commercially available products are certified with OpenADR™ logic. These products are expanding new uses for automated demand response.

Building on these efforts, the Energy Commission has initiated 15 EPIC projects to expand the ability of automated demand response to integrate DER in key market sectors including residential, commercial, industrial, water and transportation.

Affordable Zero Net Energy Buildings

California has set a goal of achieving zero-net-energy (ZNE) for all new residential homes and businesses by 2020 and 2030, respectively. While many of the technologies and measures needed to cost-effectively reach ZNE exist for many building types, they have not been deployed sufficiently to overcome the learning curve that can add delays and costs. Ongoing projects are helping builders evaluate the most technically feasible and cost-effective approaches to constructing high-performance attics and walls to enhance energy efficiency and minimize moisture issues. Six new demonstration projects initiated in 2016 to show the value and benefits of getting to or near ZNE in disadvantaged or low-income communities in Fresno, Ontario, and San Francisco. These projects emphasize large-scale deployment of affordable and comfortable ZNE homes, and retrofit demonstrations of existing buildings.

Figure 3 Low-Cost Ground-Coupled Heat Pumps Being Installed

Source: California Energy Commission, Energy Innovation Showcase

Even as buildings move closer to ZNE, the growing number of electronic devices and their associated energy use will challenge the state's ability to maintain electricity demand levels. In 2016 under EPIC, the Energy Commission launched eight new projects that aim to increase the efficiency of devices and appliances, reduce standby energy use, improve power management, and monitor energy use.

Figure 4 Eos' Znyth Battery Technology in Distributed Energy Storage Systems

Source: California Energy Commission, Energy Innovation Showcase

Creating a Market for Energy Storage

Assembly Bill 2514 (Skinner, Chapter 469, Statues of 2010), recognizes the importance of energy storage in meeting the state's energy goals. AB 2514 directed the CPUC to launch a proceeding to consider whether to establish an energy storage procurement requirement. Prior to the proceeding, the Energy Commission and the U.S. Department of Energy (DOE) co-funded several large-scale storage demonstration projects. These projects tested different use cases for storage, the results of which helped inform the storage procurement targets adopted by the CPUC, establishing one of the first markets for energy storage.

Through the EPIC program, the Energy Commission is strengthening the market for energy storage, funding the first demonstrations of several new storage technologies. In its first round of storage procurement, Pacific Gas and Electric Co. (PG&E) selected two of the Energy Commission's EPIC funded recipients: Amber Kinetics of Union City (Alameda County) for 20 MW of flywheels and Eos Energy Storage for 10 MW of zinc-air batteries. Amber Kinetics and Eos Energy Storage will be in a strong position to expand their customer base during future competitive selection rounds of storage procurement, scheduled for 2018 and 2020.

Taking Action at the Local Levels

State level officials are not the only California leaders developing and implementing new policies to meet energy and climate change goals. Many California local jurisdictions are also taking action. More than 200 cities and counties have adopted or are developing climate action plans, and a number of local communities are voluntarily exceeding the Title 24 building efficiency standards. In addition, several cities have adopted aggressive renewable energy targets with a number of others studying the feasibility.

The Energy Commission, under EPIC, is helping local jurisdictions' efforts to increase the resiliency of their communities and achieve their clean energy targets. This includes downscaling climate modeling to regional levels so these tools can inform local planning decisions. Under EPIC in 2015, the Energy Commission initiated four projects examining electricity sector vulnerabilities and adaptation options. One project with ICF International is investigating impacts of sea level rise for San Diego Gas & Electric Co. (SDG&E) assets. The other projects will identify climate vulnerabilities and adaptation measures that can be adopted in future utility risk-planning.

In 2016, the Energy Commission launched "The EPIC Challenge," a two-phase competition that challenges multi-disciplinary teams to conceptualize and build "Advanced Energy Communities." Thirteen teams were selected and funded for the first phase of the competition to develop and pilot innovative approaches for planning, permitting and financing Advanced Energy Communities that can be replicated in other communities. The second phase is not yet underway.

Building a Resilient Electricity System

Governor Edmund G. Brown Jr's Executive Order B-30-15 directed state agencies to factor climate change into their planning and investment decisions. Through EPIC, the Energy Commission is accelerating new technologies that can help improve the resiliency of the electricity system to climate change impacts. This effort includes a portfolio of microgrid projects that can maintain power to critical services and facilities during grid outages using clean onsite distributed energy resources. One of these projects, the Kaiser Permanente Microgrid, has already demonstrated success working with PG&E on interconnection and with the Office of Statewide Health Planning and Development on permitting. If the project meets its performance objectives, Kaiser plans to develop other microgrids at more than 35 Kaiser Permanente hospitals statewide, and provide a replicable model for other hospitals in California.

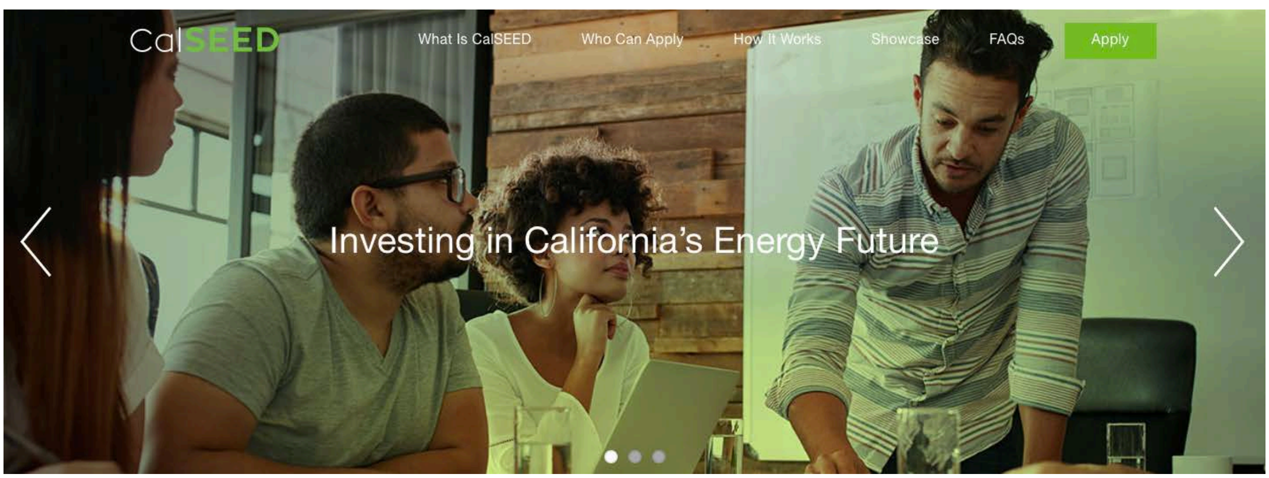
Climate change has also contributed to significant drought conditions that have stressed the electricity system and the water sector. To develop new water and energy technologies and approaches to make California more drought-resilient, the Energy Commission initiated 14 projects that will advance on-site water recycling, demonstrate energy-efficient water and wastewater treatment techniques, advance hybrid air/water cooling systems, enhance energy-efficient agricultural water-use practices, and test innovative methods for water-leak detection. A subset of three projects will also help treat nontraditional water sources for municipal and industrial use while increasing the energy efficiency of treatment processes.

Launching an Energy Innovation Ecosystem

Most entrepreneurs and early-stage start-ups have strong engineering and scientific backgrounds, but little understanding and knowledge of the business aspects needed to successfully commercialize their inventions. In addition, most lack early seed funding to prove the feasibility of their concepts, and lack access to state-of-the-art facilities for rapid prototyping and testing of their technology.

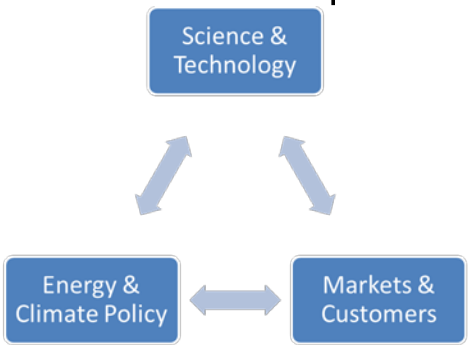
In 2016, the Energy Commission launched the California Energy Innovation Ecosystem, which includes four regional energy innovation clusters providing and coordinating key resources, mentoring, and services needed by entrepreneurs. The Energy Commission also kicked off a small grant program called the California Sustainable Energy Entrepreneur Development Initiative, or CalSEED. CalSEED provides funding to enable entrepreneurs to prove the early technical and commercial feasibility of their new science concepts; prepares them to succeed in obtaining larger private and public funding awards; and manages the resulting projects.

Figure 5 CalSEED Homepage



Source: California Sustainable Energy Entrepreneurship Initiative Website http://calseed.fund/

Figure 6 Synergies of Clean Energy Research and Development



The Energy Commission's administration of EPIC seeks to optimize linkages between technologies, markets and policies to drive the electricity sector's transformation.

Source: California Energy Commission

Customer Engagement: Moving From Lab to Impact

A critical aspect of the first two EPIC investment plans has been providing customers an opportunity to test emerging technologies by funding first demonstrations. These projects are an important bridge between R&D and commercialization, providing information to potential customers and feedback to developers about technologies performance in actual practice and the features that need the most improvement for commercial success.

The Energy Commission is currently supporting one company's efforts to bring high-tech products to the agricultural sector by funding the deployment of data analytics solutions. As part of this project, Pow Wow installed their products on multiple farms in California. These installations were followed by three field days in which farmers and other industry stakeholders were invited to see the technology in action, ask questions, and provide feedback on how the technology could be modified to gain greater customer acceptance. If successfully adopted, this technology could

Figure 7 Clean Energy Technologies Deployed in Agriculture can Save Energy and Water

Source: www.123rf.com

significantly reduce the water and energy needed to maintain agricultural production.

Demonstration projects also address critical issues facing the state. Forest management agencies have identified the need for technology solutions to sustainably manage forest residue resulting from the tree mortality crisis. Through EPIC, the Energy Commission is currently funding pilot demonstrations of multiple new technologies that potentially meet the operational needs of forest management activities. These technologies are capable of converting forest biomass into renewable energy, and can be readily moved to different forest locations to lower feedstock transport costs.

Going Forward

California has long been recognized as a global leader in energy policy and innovation, due in part to the state's investment in energy research and development. Since 2014, the EPIC program, building upon the Public Interest Energy Research (PIER) program, has supported some of the most cutting-edge technologies and science-based approaches in the world. Over the next few years, hundreds of EPIC-funded projects will reach completion, the results of which will provide information and cost-saving opportunities to inform critical energy-related decisions.

THE ENERGY COMMISSION HOSTED 44 INTERNATIONAL DELEGATIONS FROM MORE THAN 60 COUNTRIES AND SIX CONTINENTS

CALIFORNIA ENERGY COMMISSION

The research initiatives presented in this Investment Plan will ensure the Energy Commission's EPIC program continues to provide energy leadership and innovation necessary to carry out California's progressive energy policies and inform decisions and actions at local, state, federal and international levels; and further position California as the primary destination for top talent and investment in the clean energy economy.

CHAPTER 1: INTRODUCTION

The Electric Program Investment Charge

In 2011, the CPUC established the EPIC program to address a critical gap in California's clean energy policy.

The EPIC Program provides approximately $162 million annually to fund investments that will advance pre-commercial clean energy technologies and approaches for the benefit of electricity ratepayers of California's three largest electric investor-owned utilities. The CPUC, in establishing EPIC, named the Energy Commission as one of four administrators – along with Pacific Gas and Electric Company, San Diego Gas & Electric Company, and Southern California Edison Company. The Energy Commission administers 80 percent of the EPIC funding, investing in the areas of applied research and development, technology demonstration and deployment, and market facilitation.

The mandatory, primary guiding principle for these investments is to provide electricity ratepayer benefits to promote greater reliability, lower costs and increase safety. Complementary guiding principles include:

- Providing societal benefits by lowering costs and increasing safety.
- Reducing greenhouse gas emissions in the electricity sector at the lowest possible cost.
- Supporting California's loading order to meet energy needs first with energy efficiency and demand response, then renewable energy (distributed generation and utility scale), and third with clean conventional electricity supply.
- Supporting low-emission vehicles and transportation.
- Providing economic development.
- Using ratepayer funds efficiently.

Additionally, EPIC considers the principles conveyed in Public Utilities Code Sections 740.1 and 8360, which govern utility expenditures in the areas of research, development, and demonstration (RD&D) and smart grid, to serve as guidance.

EPIC ADMINISTRATIVE DIRECTION

Senate Bill (SB) 96 guides the Energy Commission in its administration of the EPIC Program. Specifically, SB 96 directs the Energy Commission to award EPIC funds for projects that will benefit electricity ratepayers and lead to technological advancement and breakthroughs to overcome the barriers that prevent achieving the state's statutory energy goals. SB 96 also directs the Energy Commission to select EPIC investments to result in a portfolio of projects that is strategically focused and sufficiently narrow to advance the most significant technological challenges that shall include, but not be limited to, energy storage, renewable energy and integration into the electrical grid, energy efficiency, integration of electric vehicles into the electrical grid, and accurately forecasting the availability of renewable energy for integration into the grid.

Section 740.1 states that in evaluating RD&D projects, consideration will be given to:

- Projects that provide a reasonable likelihood of ratepayer benefits.

- Minimizing projects with a low probability of success.
- Projects consistent with the utility corporation's resource plan.
- Projects that do not duplicate previous or current research by other electrical or gas corporations or research organizations.
- Projects that support one or more of the following objectives:
    - Environmental improvement.
    - Public and employee safety.
    - Conservation by efficient resource use or by reducing or shifting system load.
    - Developing new resources and processes, particularly renewable resources and processes that further energy supply technologies.
    - Improve operating efficiency and reliability or otherwise reduce operating costs

Section 8360 outlines the requirements for the state's electrical T&D system to maintain safe, reliable, efficient, and secure electrical service to meet future growth in demand and achieve the following:

- Increased use of cost-effective digital information and control technology to improve reliability, security, and efficiency of the electric grid.
- Dynamic optimization of grid operations and resources, including appropriate consideration for asset management and use of related grid operations and resources, with cost-effective full cybersecurity.
- Deployment and integration of cost-effective distributed resources and generation, including renewable resources.
- Development and incorporation of cost-effective demand response (DR), demand-side resources, and energy-efficient resources.
- Deployment of cost-effective smart technologies, including real-time, automated, and interactive technologies that improve the physical operation of appliances and consumer devices for metering, communications concerning grid operations and status, and distribution automation.
- Integration of cost-effective "smart" appliances and consumer devices.
- Deployment and integration of cost-effective advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning.
- Provide consumers with timely information and control options.
- Develop standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid.
- Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services.

Program Areas

The CPUC's approach to investments in clean energy research recognizes many market-driven scientific and financial barriers by allocated funding to the following three interconnected stages of development:

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.

Strategic Framework

In January 2017, Energy Commission staff developed a strategic framework to help guide the Commission's planning and implementation of EPIC across triennial investment cycles. The Energy Commission presented a draft version of the strategic framework to stakeholders at a scoping workshop on February 3, 2017. The draft strategic framework consisted of eight strategic objectives. Stakeholder participants were asked to organize their proposed funding initiative under one of the themes or propose a new theme that staff should consider.

Strategic Framework Purpose

- Guide the Energy Commission's planning and implementation of EPIC across triennial investment plan cycles.
- Communicate a consistent set of priorities to stakeholders.
- Illustrate how projects funded through EPIC are building towards a future vision of the electricity system encapsulated in state energy policy goals.
- Help simplify strategic alignment of the Energy Commission's EPIC investments with other public energy programs and policies.

The strategic framework consists of eight strategic objectives. Chapters 2-9 of this report provide an overview of each strategic objective, list previous and planned investments the Energy Commission has made under each strategic objective, and describe the proposed funding initiatives for the *EPIC 2018 – 2020 Investment Plan*.

Strategic Objectives

1. Advance Technology Solutions for Continuous Energy Savings in Buildings and Facilities
2. Accelerate Widespread Customer Adoption of Distributed Energy Resources
3. Increase System Flexibility and Stability from Low-Carbon Resources
4. Improve the Cost-competitiveness of Renewable Generation
5. Maximize Synergies in the Water-Energy-Food Nexus
6. Create a Statewide Ecosystem for Incubating New Energy Innovations
7. Develop Tools and Analysis to Inform State Energy Policy and Planning
8. Catalyze Clean Energy Investment in Underrepresented and Disadvantaged Communities

The EPIC 2018 – 2020 Triennial Investment Plan

The *EPIC 2018 – 2020 Triennial Investment Plan* presents the Energy Commission's proposed strategy for administering this three-year funding allocation. The proposed initiatives in this plan cut across several themes that reflect the state's priorities and the increased importance of the Electric Program Investment Charge to California in light of the changing federal landscape.

Engaging and Empowering Local Governments

The role of local governments in combating climate change is becoming increasingly important. Cities, counties and other local agencies have several policy tools for deploying clean energy technologies in their jurisdictions and increasing the resiliency of their communities. The Energy Commission, under the previous two EPIC plans, has provided funding to pilot new tools that will help local governments streamline the deployment of DERs in their communities, and expand the application of new technology solutions, such as low-carbon-powered microgrids, to municipal facilities.

For the third investment plan, the Energy Commission looks to strengthen its engagement with local governments. This engagement includes proposed initiatives to design and scale-up "soft innovations" for financing and deploying DER solutions at the local levels, as well as advance deployment of community-scale energy solutions.

Emphasis on Equity

Under the previous two investment plans, the Energy Commission has taken steps to ensure EPIC investments include targeted benefits for disadvantaged communities and low-income customers. This has included either awarding preference points for projects with a demonstration site in a disadvantaged community or requiring project locations to be in a disadvantaged community. These projects will provide direct benefits to disadvantaged communities and serve as important case studies going forward.

For the third investment plan, the Energy Commission, in accordance with the Low-Income Barriers Study, will target a minimum of 25 percent of EPIC technology demonstration and deployment funding for sites located in disadvantaged communities.[12] These funds will focus on scaling-up technology solutions best suited to meet the needs of residents in disadvantaged communities as well as the businesses and institutions that serve them. The funding initiatives in this plan will also develop data-driven tools that can be used to better target public clean energy investments to maximize related impacts to disadvantaged communities.

Enabling Market Growth of DER

The proposed initiatives under this plan will support the growth of DER at both the system level and the customer level. The CPUC DER Action Plan takes a market-driven, technology-agnostic approach to accelerate the growth of DERs. The funding initiatives in this plan will advance the infrastructure technologies, including smart inverters and communication protocols, that will be needed to operationalize the strategies in the DER Action Plan.

12 Scavo, Jordan, Suzanne Korosec, Esteban Guerrero, Bill Pennington, and Pamela Doughman. 2016. Low-Income Barriers Study, Part A: Overcoming Barriers to Energy Efficiency and Renewables for Low-income customers and Small Business Contracting Opportunities in Disadvantaged Communities. California Energy Commission. Publication Number: CEC-300-2016-009-CMF

At the customer level, the proposed initiatives will help overcome customer concerns by continuing to demonstrate and test different DER technology packages in specific market segments and applications to identify those that will provide the best financial returns for customers and technology providers.

California Leadership in Intelligent Energy Innovation

The likely decline in federal funding for climate resilient energy research will create further challenges for clean energy entrepreneurs. California's leadership and steadfast commitment to a low carbon energy future is elevated in this new federal landscape, making creative innovations necessary.

Even prior to this, a number of studies and organizations have highlighted the need for more strategic approaches to develop and scale-up new energy inventions to better meet the threshold of private sector investment.

In prior investment plans, the Energy Commission launched the first phase of a larger effort to fill critical gaps in the California Energy Innovation Ecosystem. The 2018-2020 funding initiatives will further expand this effort by continuing to leverage, align and expand California's existing assets to build a more interconnected and inclusive statewide energy innovation ecosystem.

Operationalize Climate Change Science

Climate change poses an ever-growing threat to California's electricity system. As federal priorities appear to be changing, there is a greater need for California to demonstrate leadership to strategically engage the energy sector in continued resilience efforts. The Energy Commission along with the CPUC has already begun the groundwork to promote resilience through the Energy Sector Adaptation Implementation Working Group.

This plan proposes increased funding for climate research to ensure California's decision-makers and planners have the analytical tools and models to incorporate implications of climate change into the planning and decision-making aspects of the electricity sector. A key focus will be on bridging the gap between actionable information and action.

Pushing the Internet of Things Market Forward

The Internet of Things (IoT) has the potential to drive enormous efficiency improvements and new functionality and features in the electricity system. A number of competing standards and protocols are currently being developed and proposed for grid-connected devices including storage, electric vehicles, and controllable building loads. However, the IoT industry has been slowed due to uncertainties over which of these protocols and standards will move forward. The Energy Commission will help push the IoT market forward by evaluating competing standards and protocols and including the best options in EPIC funding opportunities for grid-connected devices and technologies.

EPIC Administration

Program administration, like technology development, is a process of iteration and incremental advancements. The Energy Commission will continue to identify and incorporate improvements into the administration of EPIC. In September 2016, Energy Commission staff held a public workshop to better understand potential barriers that may deter private sector companies from applying for EPIC funding opportunities. Workshop participants, including entrepreneurs and private investors, raised concerns over intellectual property language that potentially grants IOU's or other load-serving entities a royalty-free license to IP developed with EPIC funds. Private sector companies interpreted the language to mean that IOU's or other load serving entities could take their intellectual property if private sector companies enter into an EPIC award agreement.

The Energy Commission seeks to clarify this term as applicable to all investment plans to what it believes is the intent to grant load-serving entities (LSE) with a free license to use analytical tools and models developed with EPIC funds, such as the recently developed StorageVET™, that can be used for distribution planning and decision-making purposes that benefit electric ratepayers. No licenses are to be granted for any other type of technology developed. For example, if an EPIC recipient developed a new type of solar PV technology, no license will be granted to an LSE since they would not be manufacturing developed EPIC technologies.

The Energy Commission and the CPUC would still retain march-in rights to obtain unused intellectual property if it is in the best interest of the electric ratepayers. Royalty provisions would also be retained. See the section *Intellectual Property* starting on page 265 for more detail.

EPIC Investment Areas and Funding

As mentioned earlier, the *EPIC 2018 – 2020 Investment Plan* is organized by eight strategic objective themes each with multiple sub-themes and funding initiatives. The strategic themes cut across all three program areas. Table 1 below shows the proposed budget allocation divided by program area, as well as proposed administrative costs.

Table 1: California Energy Commission EPIC Funding by Program Area 2018 – 2020 (millions $)[13]

Program Area	**Amount**
Applied Research and Development	$140
Technology Deployment and Demonstration	$151.7
Market Facilitation	$58.3
Program Funding Total	**$350**
Administration	$38.8
Total EPIC 2018-2020 Funding	$388.8

Source: California Energy Commission

13 Any additional funds that may be allocated to the Energy Commission as a result of any CPI adjustment will be used to increase the budget proportionally across all areas.

CHAPTER 2
Theme 1: Advance Technology Solutions for Continued Energy Savings in Buildings and Facilities

Since 1975, energy efficiency has been at the forefront of California's energy policy due to the associated multiple economic and environmental benefits. California's emphasis on energy efficiency has helped limit electricity consumption growth in the state to roughly 1 percent annually. Energy efficiency has also been a key strategy for achieving the state's greenhouse gas emissions reduction goals.

Senate Bill 350 (De León, Chapter 547, Statutes of 2015), recognizing the role of energy efficiency in meeting the state's climate goals, set a target for California to double statewide energy efficiency savings by 2030. To achieve this target, California will likely need to make exponential energy efficiency gains in the upcoming decade, especially when accounting for growing electricity demand from lighting and space cooling loads from climate change impacts and further electrification of the energy sector. Achieving these energy efficiency gains will become challenging as fewer low-hanging opportunities exist for energy savings, especially in new construction.

The funding initiatives described in this chapter focus on technology advancements to drive cost and performance improvements of energy efficiency components. These initiatives aim to:

Accelerate the adoption rate of energy efficiency upgrades in existing buildings and facilities

The existing building stock represents the greatest opportunity for reducing electricity consumption. It also represents a hard-to-reach market sector. Current technologies in most cases do not meet acceptable payback periods necessary to drive large-scale market adoption of energy efficiency upgrades without policy changes. In addition, the invasive nature of some energy efficiency upgrades, combined with high customer acquisition costs and long equipment turnover, create a limited window for when customers look to make energy efficiency upgrades. New technology advancements and strategies are needed to overcome these market barriers and take advantage of innovations in lighting, building envelopes, heating and cooling, controls, and consumer electronics.

"INNOVATION IN THE BUILDINGS SECTOR WILL INCREASE THE EFFECTIVENESS AND LOWER THE COSTS OF ACHIEVING DEEP EMISSIONS REDUCTIONS."

THE WHITE HOUSE
UNITED STATES MID-CENTURY STRATEGY FOR DEEP DECARBONIZATION[14]

Increase cost-effective options for energy efficiency in future buildings

California has made substantial progress in improving the energy efficiency of new

14 United States Mid-Century Strategy for Deep Carbonization, November 2016, https://obamawhitehouse.archives.gov/sites/default/files/docs/mid_century_strategy_report-final.pdf

construction through technology innovation incentive programs and building energy efficiency standards. The state has set goals to require all new residential and commercial buildings to be zero net energy (ZNE) by 2020 and 2030, respectively. The greatest remaining opportunities for energy efficiency improvements in new construction are likely to be integrated technology designs that optimize components of the building ecosystem. These innovations could change how energy efficiency equipment and devices are installed and operated. For instances, lights and heating and cooling systems could be controlled by smart devices rather than switches and traditional thermostats. Integrated and collaborative approaches involving multiple entities – including architects, engineers, building designers and developers, original equipment/appliance manufacturers, equipment vendors, construction industry, real estate industry and others – will be needed to move these innovations forward. Examples include: envelope improvements in single and multifamily buildings and in factory built buildings; tests of direct current (DC) applications; and development of appropriate appliances for DC buildings.

Electrify traditionally non-electric appliances and equipment

A key strategy for decarbonizing the energy sector is electrification coupled with grid power dominated by renewable generation. The largest non-electric end uses for residential and most commercial buildings are space heating and water heating. Electric technology options, such as electric heat pumps for space and water heating, exist for these end uses but have not significantly penetrated the market due to capital and operating costs compared to natural gas systems. Also, electric heat pumps are less effective in cold climates. Electrification of the industrial sector is likely to be much more challenging because many industrial end-users have high thermal requirements. To achieve widespread diffusion, new technology solutions are needed that provide cost, reliability, and thermal output comparable to conventional solutions.

"CONVENTIONAL BOILER USE AND PROCESS HEATING ARE TWO INDUSTRIAL END USES WITH MEANINGFUL TECHNICAL POTENTIAL FOR ELECTRIFICATION"

US DEPARTMENT OF ENERGY, SECOND INSTALLMENT OF THE QUADRENNIAL ENERGY REVIEW[15]

Improve the energy efficiency of the industrial sector

The industrial sector is the third largest user of electricity in California.[16] Large pieces of equipment such as kilns, furnaces, and boilers typically operate for 20 years or more.[17] Though energy savings are considered, technology investment decisions are frequently driven by non-energy benefits such as increased productivity and product quality.[18] To achieve acceptance, new technologies and strategies are needed to identify less invasive, cost-effective approaches that can be demonstrated to show energy and other benefits compared to current equipment.

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15 Department of Energy, *Quadrennial Energy Review Transforming the Nation's Electricity System: The Second Installment of the QER*. 2017 https://www.energy.gov/sites/prod/files/2017/02/f34/Quadrennial%20Energy%20Review--Second%20Installment%20%28Full%20Report%29.pdf

16 California Energy Commission, California Energy Demand 2016-2026, Revised Electricity Forecast, January 2016, http://docketpublic.energy.ca.gov/PublicDocuments/15-IEPR-03/TN207439_20160115T152221_California_Energy_Demand_20162026_Revised_Electricity_Forecast.pdf

17 Worrell, E., et al., Emerging Energy Efficient Technologies for Industry, https://www.osti.gov/scitech/servlets/purl/920147-u4MkO8/

18 Ibid.

1.1 Accelerate Product Development and Market Acceptance of Solid-State Lighting Technologies and Designs

Lighting continues to represent a significant opportunity for reducing end-use consumption of electricity in California. Over the past decade, solid state lighting (SSL) has emerged offering a tremendous opportunity to improve the efficiency, performance, and value of lighting and to create new applications and benefits. Widespread adoption of SSL such as light-emitting diode (LEDs) products has the potential for tremendous savings in lighting energy and demand, relative to other available lighting technologies.

Several challenges stand in the way of achieving the full energy-saving potential of SSL. Although SSL products now are available for many applications – from bulbs for homes and commercial buildings to street lights in the cities – SSL technology is actually still in its infancy. Continued innovation in increased efficiency and improved lighting quality, as well as improved cost-competitiveness, is needed to realize the full energy savings and non-energy benefits potential of the technology.

"SSL ALSO HAS THE POTENTIAL TO HAVE PROFOUND BENEFICIAL IMPACTS ON THE ENVIRONMENT, HORTICULTURE, LIVESTOCK PRODUCTION, TRANSPORTATION SAFETY, HUMAN HEALTH, AND PRODUCTIVITY."
DEPARTMENT OF ENERGY SOLID-STATE LIGHTING R&D PLAN[19]

Most SSL technologies have been developed in form factors designed to be used with, or in place of, legacy lighting fixtures and applications – most notably the A19 lamp commonly found throughout most households. Early R&D efforts focused on improving the luminous efficacy (lumens/watt) while lowering the manufacturing costs of LEDs.

"IF THERE IS TO BE A SECOND WAVE, SSL TECHNOLOGY WILL NEED NEW ADVANCES THAT ENCOMPASS, BEYOND EFFICACY ALONE, THE QUALITY AND FORM FACTORS OF LIGHTING, THEIR CONNECTEDNESS AND CONTROLLABILITY, AND THEIR COST-EFFECTIVE INSERTION INTO NEW APPLICATIONS"
NATIONAL ACADEMY PRESS, ASSESSMENT OF SOLID-STATE LIGHTING 2016[20]

In recent years, R&D has focused on improving other performance characteristics – such as the color rendering index and minimum lifespan – to better satisfy and meet consumer expectations. This has resulted in the 60 watt equivalent A19 LED replacement bulb with a retail price below $5 per bulb.

To avoid the quality and performance issues that prevented compact fluorescent lamps from achieving higher market penetration, the main goal of EPIC research on LED technology has been to achieve high performance and quality. The research focused on developing high quality screw based replacement lamp, linear tubular LED lamp and, spectrally optimized LED

19 Department of Energy, *Solid-State Lighting R&D Plan*. 2016. https://energy.gov/sites/prod/files/2016/06/f32/ssl_rd-plan_%20jun2016_2.pdf

20 National Academies of Sciences, Engineering, and Medicine. 2016. Assessment of Advanced Solid-State Lighting, Phase 2. Washington, DC: The National Academies Press. https://www.nap.edu/catalog/24619/assessment-of-solid-state-lighting-phase-two

luminaires. Information from this research has helped inform California's appliance standards.

As a result, in 2016, the Energy Commission adopted new standards to promote LEDs for general purpose lighting and small-diameter directional lamps often used in track lighting. These new standards are expected to go into effect in 2018 and the Energy Commission has issued a Voluntary LED Quality Specification that allows manufactures to certify compliant products before that date.[21]

KEY TECHNICAL AND MARKET CHALLENGES

Despite these advancements, solid-state lighting represents a small percentage of existing lighting installations. Only 6.4 percent of U.S. general illumination was provided by LEDs in 2015.[22] For many consumers, higher first costs and longer payback periods relative to conventional lighting products remain a barrier to adoption. Moreover, many consumers who use incandescent bulbs or purchased Compact Fluorescent (CFL) bulbs are reluctant to trade in for more expensive SSL technology due to significant cost differences, in spite of the improved performance, lighting quality and flexibility-of-control options. For solid-state lighting technologies to reach their potential, the following barriers need to be addressed:

Improve materials and manufacturing processes to overcome current limitations in the cost and technical performance of solid-state lighting technologies

Improvements in LED package efficacy are becoming harder to achieve, "R&D is required to address fundamental technological barriers such as current efficiency droop, efficiency gap of green LEDs, and the need to develop new high-efficiency, narrow linewidth down-converter materials."[23]

Demonstrate the value of new lighting applications and features

Solid-state lighting offers many benefits over conventional lighting technologies. LED and Organic Light-Emitting Diode (OLED) lighting can be engineered to have spectral power distributions that match specific applications or are controllable such that the spectrum of the emitted light can be dynamically changed. In addition, solid-state lighting can offer a new range of features and design flexibility that provides additional value for customers. For example, new internet systems are being developed that use light waves from a standard LED light bulb to transmit data wirelessly. Known as Li-Fi, this technology could benefit customers over current Wi-Fi technology through increased data speeds and increased security since light cannot pass through walls. Early research indicates that artificial lighting such as fluorescent, and regular LEDs emit a spectrum of light with a high concentration of blue wavelength (white light) that disturbs the body's circadian rhythm, suppresses melatonin levels, and could harm humans and wildlife. Recently, some testing of circadian sensitive LED lighting in hospitals and senior centers homes have found that tailored LED lighting can improve sleep and vision, prevents falls and enhance the overall health and sense of well-being of patients and residents.[24]

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21 Soheila Pasha, Peter Strait, Patrick Saxton. 2016. *Voluntary California Quality Light-Emitting Diode (LED) Lamp Specification 3.0.* California Energy Commission. Publication Number: CEC-400-2016-024-SF.

22 Department of Energy, *Solid-State Lighting R&D Plan.* 2016. https://energy.gov/sites/prod/files/2016/06/f32/ssl_rd-plan_%20jun2016_2.pdf

23 Ibid.

24 Department of Energy, *Tuning the Light in Senior Care: Evaluating a Trial LED Lighting System at the*

Develop novel lighting design concepts that use solid-state lighting form factors[25]

Current LEDs were designed to resemble legacy lighting to promote customer acceptance of these new technologies and ensure compatibility with existing lighting technology and systems. However, integrating solid-state lighting into legacy forms present many technical challenges that can be costly and inefficient. Moreover, legacy lighting forms fail to exploit the unique features and design flexibility associated with solid-state lighting. For instance, LED light sources can emit the same light as traditional light sources using smaller fixtures or different shapes.[26] Engineering solid-state lighting into optimal forms factors could reduce solid-state lighting costs while providing customers with better lighting such as thin-film modules for lighting a space without using traditional lamps or even luminaires. This represents a major shift in how lighting systems are designed and installed and will require collaboration among architects, manufacturers, the home construction industry, lighting designers, and other stakeholders.

ACC Care Center in Sacramento, CA. 2016 https://energy.gov/sites/prod/files/2016/09/f33/2016_gateway-acc.pdf

25 Form factor describes the shape of the luminaire that accommodates the size and shape of lamps and ballasts. Source: http://www.accessfixtures.com/how-are-leds-changing-the-form-factor-of-luminaires/

26 http://www.accessfixtures.com/how-are-leds-changing-the-form-factor-of-luminaires/

Table 2: Previous and Planned EPIC Investments on Lighting

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Technical and Cost Advancements	New Generation of LED Lighting Solutions (EPC-14-011)	No current or planned investments
Novel LED Applications	No projects	No current or planned investments
Lighting Designs	No projects	No current or planned investments

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

The U.S. Department of Energy (DOE) identifies four primary areas of focus for solid-state lighting research: Core Technology R&D, Product Development, Manufacturing R&D, and Technology Application R&D. Core Technology R&D comprises the majority of R&D spending and focuses on applied research to improve efficiency, cost, and performance. The Energy Commission's initiatives will leverage DOE's funding by focusing on Product Development and Technology Application R&D.

Initiative 1.1.1 Pilot and Test New Solid-State Lighting Features and Applications with Energy Savings and Added Functionality

Description

In addition to being energy efficient, solid state lighting can increase the functionality of lighting systems and design spaces that are attuned and customized to the needs of a particular space or use. This initiative will evaluate what value-added features would increase adoption of energy-efficient SSL technology.

Data will be collected to determine value-added features, such as health benefits to humans, to encourage increased adoption of SSL technology. Data will also be collected on the estimated cost for each feature, the total energy use of the increased functionality, impact on the lighting system, and overall resulting benefits. Pilots of the best value-added features will be conducted in various residential, commercial and industrial settings to determine whether the value-added functionality would increase uptake of SSL technology. Value-added features to be analyzed could include color tuning, circadian sensitive lighting, daylighting coupling, internal energy metering, voice recognition controls, integration with other smart controls, egress illumination, demand side management, and internet connectivity for remote control.

Impact if Successful	Inclusion of value-added features into SSL technologies could lead to greater adoption in harder to reach market segments such as hospitals and other healthcare facilities. In addition to energy savings to California ratepayers, the new features could improve safety, alertness and the ability to customize light features for a particular task.
Primary Users and/or Beneficiaries	In key market segments such as hospitals, healthcare facilities, residential buildings, and retail establishments, color tuning and circadian sensitive lighting can improve the occupant experience, such as safety and alertness. Also, intuitive user interfaces are needed to promote the use of added features when coupled with traditional lamps and luminaires.
Metrics and Performance Indicators	Increased adoption of SSL lighting, reduced operation and maintenance costs, and reduced energy use for lighting.
Topic(s) addressed	Novel LED applications
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development

Initiative 1.1.2 Test Novel Luminaire Systems Architecture and Form Factors That Leverage the Unique Properties of LEDS

Description	Current SSL has been packed into conventional form factors and placement in buildings. New SSL technology offers opportunities for novel fixture geometries and integration to significantly accelerate SSL adoption in applications such as hospitality, retail, healthcare, outdoor lighting and signage. This includes ultra-thin fixture designs, novel form factors, and unique physical characteristics that cannot be obtained with incumbent fluorescent, incandescent or high intensity discharge lamp technology. This initiative will develop, design and test new fixture arrangements that can be: 1) installed in new construction or can be easily retrofitted in buildings or facilities; 2) have high potential for energy savings; 3) can address interruption of circadian patterns in humans and wildlife, and 4) reduce light trespass and night sky pollution for outdoor fixtures.
Impact if Successful	California's unique lighting code position can be leveraged to drive adoption of these technologies into market sectors that have not previously been explored. This could include both indoor and outdoor lighting applications. For example, novel

	designs for outdoor lighting could redefine form factors for pole and street lighting into entirely new concepts. In California, non-LED streetlights represent about 70 percent of all fixtures and represent a large potential for untapped savings.
Primary Users and Beneficiaries	Commercial, institutional and industrial facilities could use and benefit from the initiative.
Metrics and Performance Indicators	Increased adoption of SSL lighting; reduced operation and maintenance costs; reduced energy use for lighting.
Topic(s) addressed	Novel LED Applications
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development

Initiative 1.1.3 $1 LED A-19 Lamp Prize

Description	Despite the wide range of added value presented by SSL technology, the higher initial cost of LEDs when compared to traditional lighting technology remains a barrier. The added features of LEDs such as spectrum controllability and internet connectivity also add to the cost. Further research is needed to continue to drive SSL cost down while maintaining product quality and feature richness. This initiative would provide a cash prize to manufacturers of LED A19 lamps that do all of the following: • Meet or exceed the light output of a 100 watt incandescent light bulb measured in lumens per watt • Meet or exceed the Energy Commission's specifications for color rendering, durability and performance • Demonstrate and install the lamp in buildings in disadvantaged communities, including residential, multifamily, small commercial and industrial buildings • Market the lamp at a cost of $1 (or no more than twice the cost of competing incandescent bulbs)
Impact if Successful	A low-cost high-quality 100-watt-equivelent A-19 LED lamp could produce substantial energy savings by replacing use of incandescent and CFL lamps in homes and businesses in California.
Primary Users and/or Beneficiaries	This initiative would be beneficial to renters, including low-income residents as well as the small commercial sector and industrial sector.

Metrics and Performance Indicators	Price and sales of 100-watt LED, incandescent, and CFL bulbs.
Topic(s) addressed	Technical and Cost Advancements
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development

Table 3 Ratepayer Benefits Summary For Sub-Theme 1.1

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transpo rtation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 1.1.1 Pilot and Test New Solid-State Lighting Features and Applications with Energy Savings and Added Functionality	X	X		X	X		X	X	
Initiative 1.1.2 Test Novel Luminaire Systems Architecture and Form Factors That Leverage the Unique Properties of LEDS	X	X	X	X	X		X	X	
Initiative 1.1.3 $1 LED A-19 Lamp Prize	X	X		X	X		X	X	

Source: California Energy Commission

1.2 Showcase Benefits of Advanced Window and Building Envelope Systems

The building envelope consists of windows, walls, roofs, foundations, and other elements of the building exterior that enclose conditioned spaces. Envelope systems fundamentally shape the heating, cooling, ventilation, and lighting requirements of buildings, which together account for 52 percent of U.S. building source energy use.[27] Not only is substantial energy saved through improved envelope performance, but comfort can be dramatically improved.

To reach the goal of all residential construction being zero net energy by 2020, one of the key areas is improving the integrity of the building envelope to achieve High Performance Attics (HPA) and High Performance Walls (HPW).[28] For the 2016 California Building Energy Efficiency Standards (Title 24, part 6), the Energy Commission included specific requirements for HPA and HPW into the code.[29] These requirements included achieving minimum levels of envelope tightness that could be achieved by various methods, such as insulation, ducts in conditioned space, hybrid systems, staggered stud construction and use of structurally insulated panels. These standards took effect on January 1, 2017. To ensure that the workforce was adequately trained to transition to HPA and HPW, the EPIC program funded on-the-job training for constructing HPAs and HPWs for new homes.

The Energy Commission and DOE have targeted research on high performance window and building envelope systems, and initiated research projects to evaluate various options and technologies, their cost effectiveness and builder level acceptance. Because first-generation products are often expensive and may have unforeseen issues, the risk-averse building industry is reluctant to try new technologies.

A testing and demonstration program can help bridge the gap between R&D and the marketplace by demonstrating and evaluating pre-commercial products in actual building conditions. These technologies have shown some level of technical and economic promise but still need larger scale deployment. The EPIC program can leverage prior research by sponsoring pilots and larger-scale demonstrations in existing or new buildings, or manufactured homes. These demonstrations have the potential to put California builders at the forefront of energy efficient technology use.

"NEXT-GENERATION WINDOWS AND ENVELOPE TECHNOLOGIES HAVE GREAT POTENTIAL TO SAVE ENERGY IN BUILDINGS, BUT TO SUCCEED, WE MUST REDUCE THE COST OF THESE TECHNOLOGIES"

DEPARTMENT OF ENERGY, WINDOWS AND BUILDING ENVELOPE RESEARCH AND DEVELOPMENT[30]

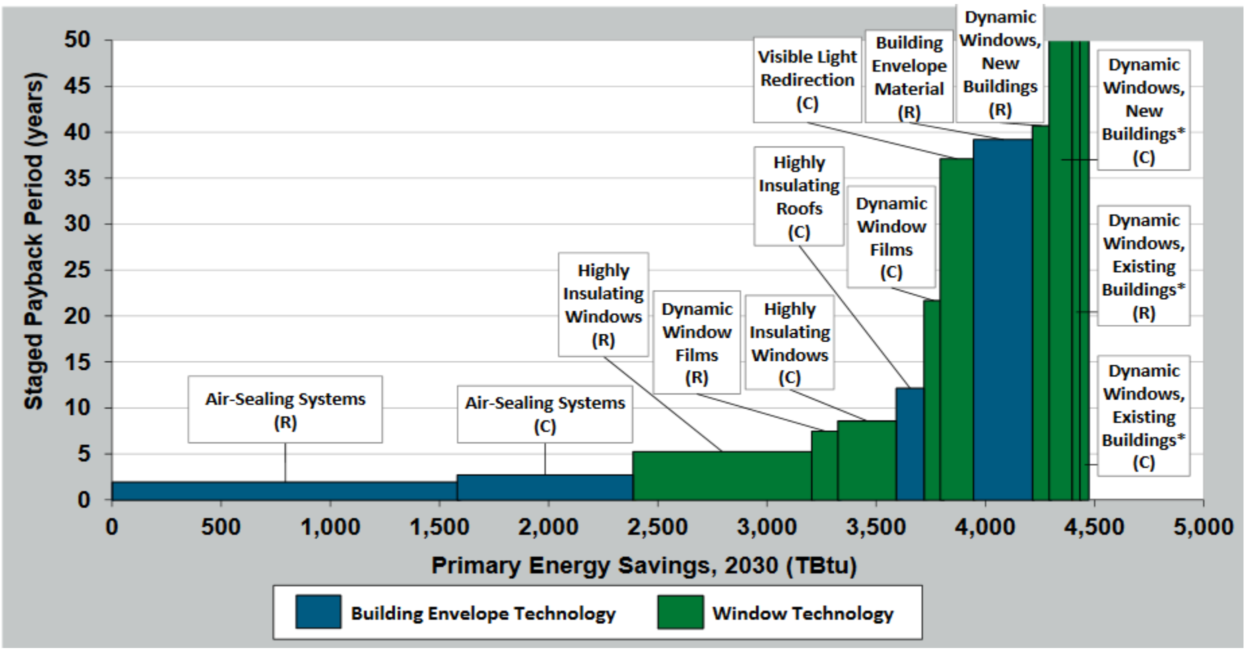
27 Department of Energy, *Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies*. 2014 https://energy.gov/sites/prod/files/2014/02/f8/BTO_windows_and_envelope_report_3.pdf

28 Shirakh, M., et al, California Energy Commission, 2016, Building Energy Efficiency Standards, Adoption Hearing, June 10 ,2015, http://www.energy.ca.gov/title24/2016standards/rulemaking/documents/2015-06-10_hearing/2015-06-10_Adoption_Hearing_Presentation.pdf

29 Ibid.

30 Ibid.

Figure 8 Building Envelope and Window Technology Payback



Source: Department of Energy, *Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies*, February 2014

Examples of new envelope technologies suitable for large-scale demonstration are the adhesive mist or liquid sealants for buildings, R-10 windows with advanced coatings and dynamic glazing, and advanced insulating materials for walls and roofs.[31] Some advanced products are recently developed, others are used in Europe but fairly unknown in the United States. Wider acceptance would reduce costs, improve comfort, and save energy. The annual energy loss from air leakage in buildings is estimated to be about 480,000 British thermal units per year (btu/yr) in California.[32]

TECHNICAL AND MARKET CHALLENGES

Trials of new technologies, especially window and building envelope systems, can be expensive due to unfamiliarity and integration issues, especially in existing buildings. The costs and perceived risks of new technologies often hinder technological innovation, along with the long payback period which can be up to 50 years. The challenge is providing superior performance at an affordable installed cost. Scaled demonstrations that showcase the additional benefits of new technologies at an affordable installed cost can help overcome these barriers.

Other energy efficient technologies are used but not widely known. Greater recognition of the benefits of these technologies can help broaden their market to achieve economies of scale that reduce costs and lower the perceived risks associated with these technologies. Contests among builders, with prizes and recognition for the highest performance buildings, can help spur use of advanced technology and increase awareness among potential buyers of the benefits of high efficiency.

Past EPIC applied research in this area focused on:

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31 UC Davis, Western Cooling Efficiency Center; https://energy.gov/eere/success-stories/articles/eere-success-story-dow-partners-ornl-commercialize-advanced-energy

32 Energy Commission staff estimate based on nationwide air leakage loss of 4 quads and assuming California is 12 percent of this amount.

- Evaluating and testing cost and energy efficient attic designs for ZNE homes.
- Solar-reflective coatings for walls.
- High-performance integrated window and façade solutions.
- Integrated ZNE home demos that include high performance attics and walls, along with other measures
- An integrated project that included building envelope sealing and HVAC improvement.
- Workforce development to help the building industry transition to high performance attics and walls.

Prior to the EPIC program, the Energy Commission funded research on envelope sealing technologies that reduce infiltration while lowering the cost of manual envelope sealant technologies. This technology showed promise for new and existing buildings and demonstrated that envelope sealing with adhesive mist more effectively sealed air leaks compared to manual technologies and was less labor intensive. Preliminary data collected by the Western Cooling Efficiency Center show this technology can reduce envelope leakage by almost 30 percent.[33]

The goal of these projects was to evaluate advanced technologies that can improve building envelopes, reduce HVAC energy use and possibly lower peak energy demand.

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33 This Old House Magazine awarded Aeroseal Best New Home Product of 2011 for its effectiveness in sealing ductwork (http://www.prweb.com/releases/2011/10/prweb8906113.htm).

Table 4: Previous and Planned EPIC Investments on Building Envelopes

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Advanced Window and Building Envelope Systems	Cost- and Energy-Efficient Attic Designs for CA Homes (EPC-14-016) Comparing Attic Approach for Zero Net Energy Homes (EPC-14-012) Solar-Reflective Cool Walls (EPC-14-010) High-Performance Integrated Window Façade Solutions for California Buildings (EPC-14-066) Workforce Instruction for Standards and Efficiency (EPC-15-009)	No current or planned investments

Source: California Energy Commission

2018-2020 FUNDING INITIATIVE

This initiative will focus on demonstrations and large-scale deployment of pre-commercial window and envelope measures that have been previously independently tested and demonstrated to have the potential for cost effectiveness. Past technologies were generally expensive and invasive to both building owners and occupants. This initiative aims to support broader adoption of advanced window and building envelope systems through scaled deployment of technologies that have shown technical and economic promise from past R&D activities. The overall goal is to increase use of advanced technologies, broaden the market, reduce costs, and demonstrate overall performance and benefits of the following:

- Windows
  - Dynamic windows (such as electrochromic)
  - Window films (insulating and reflective attachments)
- Building Envelopes
  - Building envelope material (such as advanced vacuum insulation or insulation containing phase change material)
  - Air-sealing or liquid sealing technologies (such as spray-sealing)
  - Highly insulating roofs (such as hydrophobic roofs)

The first initiative will focus on demonstrations in existing buildings to broaden the market for advanced products, document energy savings and other benefits, and increase consumer awareness of the benefits of highly efficient envelopes in buildings.

The second and third initiatives focus on builder/manufacturer prizes for installing the most efficient building envelope when compared to standard construction. The focus would be on envelopes with the least air leakage, conduction losses, and solar heat gain, but maximize for daylighting and other measures. The target is both technology advancement and quality construction. Cash prizes would be used for actual build out of homes using the winning technique(s).

Initiative 1.2.1 Deploy Next Generation Window and Building Envelope Systems in Existing Residential and Commercial Buildings

Description	Envelope systems shape the heating, cooling, ventilation and lighting requirements of buildings, which together account for about half to all the energy use in buildings. Tightening the envelope allows for sizing smaller HVAC units while providing opportunities for non-compressor type cooling and ventilation systems. This initiative will fund a large scale deployment of pre-commercial window and envelope measures that have proven on a limited scale the potential for cost effective energy savings. The deployment will occur in existing residential, multifamily and commercial buildings with a focus on older buildings. A portion of the deployment activities must occur in disadvantaged communities, which will be coordinated with Theme 8. The demonstrated technologies must have been independently tested and demonstrated to have the potential for cost effectiveness (<10 year simple payback) in Northern, Central and Southern California. Potential technologies include: • Building envelope material. • Air- and liquid-sealing technologies. • Dynamic windows and window films. • Highly insulating roofs.
Impact if Successful	This initiative aims to help accelerate the commercialization and large-scale deployment of window and building envelope technologies that have shown promise to significantly reduce HVAC energy use in buildings, while increasing occupant comfort and infrastructure value to building owners. Data from demonstrations could be used to advance future codes and standards.
Primary Users and/or Beneficiaries	Ratepayers, building owners, building occupants, building renovators, regulatory agencies, construction industry, architects and engineers, manufacturers, innovators/entrepreneurs, research community, and technology investors

Metrics and/or Performance Indicators	Projects will include performance and benefits analysis. Potential metrics include energy and cost savings, customer/occupant satisfaction, environmental benefits, and the number of post-installation deployments after the conclusion of the project.
Topic(s) addressed	Advanced window and building envelope systems
Value Chain	Demand-side Management
Program Area(s)	Technology Demonstration and Deployment

Initiative 1.2.2 Builder Competition for Best Residential Envelopes

Description	This initiative will conduct a contest for the most efficient residential building envelope. A limited number of production home builders (single and multifamily) will be selected to compete for prizes for the most efficient envelopes that can be produced at a certain price point to allow for future replication by others. Each selected builder will be required to build a minimum number of homes/multifamily buildings. A third-party firm will be selected to conduct tests on a random selection of houses and multifamily buildings, out of a larger number required to be entered in the contest. The third-party will develop a metric and test method for a quick assessment of as-built residential buildings and for multifamily buildings. This test will include such metrics as air leakage, conduction losses, solar heat gain, daylighting efficacy, and possibly subjective measures. Prize winners will receive cash prizes and recognition.
Impact if Successful	The expected outcome will benefit residential and multifamily building occupants and will result in more comfortable and energy-efficient homes compared to current construction. The initiative will have persistent benefits, because participant builders will adopt methods of construction that produce more efficient and valuable buildings which they will continue to use beyond the scope of the program. These improved methods will diffuse into the building industry because the participating builders would have demonstrated that it could be done to participate in the competition. The energy system will benefit from homes with lower heating, cooling, and lighting energy demand. Another benefit will be the development of a residential method of test that may be adaptable to building inspection and quantitative performance testing by building officials, Home Energy Rating System (HERS) raters, and others.

Primary Users and/or Beneficiaries	Ratepayers, building owners, building occupants, regulatory agencies, construction industry, architects and engineers, manufacturers, innovators/entrepreneurs, research community, and technology investors
Metrics and/or Performance Indicators	Metrics of success will include: 1) lower heating, cooling, and lighting energy demand in buildings using advanced window and building envelope systems; 2) successful development of a practical test method for residential and multifamily envelope efficiency; 3) the participation of many production homebuilders, and 4) the successful production and sustainability of many highly efficient single and multifamily buildings after the project has completed.
Topic(s) addressed	Advanced Window and Building Envelope Systems
Value Chain	Demand-side Management
Program Area(s)	Technology Demonstration and Deployment

Initiative 1.2.3 Multifamily Factory Built Homes Competition for Highly Efficient Building Envelopes

Description

With increasing housing prices, modular construction including mobile homes can offer housing that is cheaper and faster to build. Modular construction homes are assembled in a factory. However, all manufactured homes produced in the nation conform to one set of preemptive standards, the Manufactured Housing Construction Safety Standards, enforced and maintained by the U.S. Department of Housing and Urban Development. The standards contain thermal requirements that were last updated in 1994, and the requirements are far less stringent than California's Title 24. As past research focused on single family factory-built homes, this initiative will focus on multifamily units that could be installed in disadvantaged communities and will be coordinated with Theme 8. Similar to Initiative 1.2.2, this initiative will conduct a contest for the most efficient building envelope for multifamily factory-built homes. A limited number of manufactured home builders will be selected to compete for the design and construction of the most efficient envelopes.

A third-party firm will be selected to test a random selection of factory-built homes entered in the contest. The third party will develop a metric and test method for a quick assessment of the factory built multifamily buildings. This test will include such metrics as air leakage, conduction losses, solar heat gain, daylighting efficacy, and may also include comfort and other

	subjective measures. Prize winners will receive cash prizes and recognition.
Impact if Successful	The expected outcome will ultimately benefit occupants of multifamily buildings, who will be more comfortable while reducing energy costs compared to conventional practice. The initiative will have persistent benefits, because participant builders will be encouraged to adopt methods of construction that produce more efficient and valuable buildings which they will continue to use beyond the scope of the program. These improved methods would be appropriate targets for utility incentive programs to further encourage diffusion into the manufactured building industry. The energy grid will benefit from homes with lower heating, cooling, and lighting energy demand. Another benefit will be the development of a test method for factory-built homes which may be adaptable to building inspection and quantitative performance testing by building officials, HUD, and others.
Primary Users and/or Beneficiaries	Ratepayers, building owners, building occupants, regulatory agencies, construction industry, architects and engineers, factory-built home manufacturers, innovators/entrepreneurs, research community, and technology investors
Metrics and/or Performance Indicators	The metrics of success will include: 1) reduced air leakage, conduction losses, and solar heat gain; 2) daylighting efficacy; 3) successful development of a practical test method for factory built homes; 4) participation of factory home manufacturers; and 5) the adoption of the advanced envelope measures by factory homebuilders.
Topic(s) addressed	Advanced Window and Building Envelope Systems
Value Chain	Demand-side Management
Program Area(s)	Technology Demonstration and Deployment

Table 5 Ratepayer Benefits Summary For Sub-Theme 1.2

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transpo rtation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 1.2.1 Deploy Next Generation Window and Building Envelope Systems in Existing Residential and Commercial Buildings		X			X				
Initiative 1.2.2 Builder Competition for Best Residential Envelopes		X			X				
Initiative 1.2.3 Multifamily Factory Built Homes Competition for Highly Efficient Building Envelopes		X			X				

Source: California Energy Commission

1.3 Meeting the Demand for Efficient and Environmentally Friendly Heating, Ventilation and Air Conditioning and Refrigeration Systems

California's energy system is entering a period of unprecedented change. New technologies, requirements, and vulnerabilities are transforming the way people use energy. The challenge is to transition to energy systems and technologies that address energy security, economic competitiveness, and environmental responsibility while providing better more energy-efficient equipment.

Heating, ventilation, and air conditioning (HVAC) and refrigeration systems are among the largest consumers of electricity. In California, the energy required to heat and cool buildings uses roughly 40 percent of total electricity consumed. Furthermore, this demand will likely increase as California's climate warms. Southern California temperatures have increased about 3 degrees Fahrenheit in the last century. As California's population continues to grow, more people are moving to the hotter regions of the state, such as the Central Valley or the Inland Empire in Southern California. These regions require significant cooling in the summer.

"HVAC IS A SIGNIFICANT COMPONENT OF THE CALIFORNIA NET ZERO ACTION PLAN"
MARK MODERA,
WESTERN EFFICIENCY COOLING CENTER[34]

As a result of AB 32, SB 350, and Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016), there is strong impetus to focus on HVAC and refrigeration systems that have low greenhouse gas (GHG) emissions, and use refrigerants with low global warming potential (GWP) while being highly efficient. The emphasis on decarbonization puts greater emphasis on finding solutions that would apply to most California climates, are cost effective, and do negatively impact the grid. Moreover, California's cooling needs are predominantly in hot dry climates, which is different than most of the country and requires technology approaches that are climate appropriate.

"ELECTROCHEMICAL COMPRESSION HAS THE POTENTIAL TO TRULY TRANSFORM THE MARKET AWAY FROM TODAY'S VAPOR COMPRESSION SOLUTIONS"
TONY BOUZA,
DEPARTMENT OF ENERGY'S BUILDING TECHNOLOGIES OFFICE[35]

Past research focused on advanced evaporative air conditioners, radiant floor cooling, underfloor air-distribution systems, fault detection and diagnostics, variable refrigerant flow systems, and design approaches to reduce the installation cost of advanced systems. For instance, research to evaluate the benefits of radiant cooling systems resulted in the adoption of this technology by several Wal-Mart stores in hot, dry climates. A ceiling-mounted radiant cooling system for homes showed promise for reducing cooling cost. A demonstration

34 http://www.buildingefficiencyinitiative.org/articles/interview-mark-modera-toward-super-efficient-cooling-systems-dry-western-climates

35 https://energy.gov/eere/success-stories/articles/eere-success-story-xergy-develops-breakthrough-water-heater-compressor

of the use of wireless sensors for fault detection and diagnostics for HVAC, and refrigeration systems identified substantial potential for commercial buildings with central energy management systems.

Recent EPIC-funded research has focused on variable refrigerant flow, indirect evaporative cooling for commercial, building envelope sealing, two variants of smart mechanical ventilation that include pre-cooling strategies, and compressor-free evaporative air-conditioning for homes. Furthermore, new practical design and operation tools for radiant cooling and heating systems to provide a standardized guidance for radiant systems is underway. Research also includes, variable-capacity compressor and variable-speed fans using state-of-the-art inverter technology, integrated ventilation to harness fresh air for "free cooling;" intelligent dual-fuel technology to decrease energy cost and empower consumers to choose between electricity and natural gas; zonal control to prevent conditioning of unoccupied rooms; demand-response interactivity to improve grid flexibility and reliability; advanced fault detection and diagnostics to ensure proper installation, operation, and maintenance; and alternative refrigerants for improved operation and significant reductions in the potential for global warming.

Additional work is required to assess the potential to integrate advanced HVAC systems and controls with Demand Response (DR) strategies, and to standardize and validate energy and other benefits.

KEY TECHNICAL AND MARKET CHALLENGES

While building HVAC energy efficiency has increased over the past few decades, it is clear that major opportunities remain. In many areas there are still large gaps separating the energy performance of residential and commercial equipment and theoretical limits. For instance, new refrigerants may allow vapor compression cycles to achieve more than 10 percent better system efficiency. In some cases, novel HVAC mechanisms have been discovered. For example, a new electrochemical process may allow HVAC equipment to achieve or exceed a coefficient of performance of 4.5. HVAC technologies have also changed to take advantage of the external environment (for example, natural ventilation), and the opportunity to reuse waste heat generated by building equipment.

Reaching the maximum potential efficiencies will require ingenious product designs, advanced manufacturing methods that can lower costs and improve product quality, and advances in materials science where novel approaches are needed on thermal properties, heat exchange and enthalpy exchange.

Table 6: Previous and Planned EPIC Investments on HVAC

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Mechanical HVAC Systems	Climate Appropriate HVAC Systems for Commercial buildings (EPC-15-004)	Energy Efficiency HVAC Packages for Existing Residential Buildings (EPC-16-005)
	Next Generation Residential Space Conditioning System (EPC-14-021)	Benefits and Challenges in Deployment of Low GWP A3 Refrigerants in Residential and Commercial Cooling Equipment (EPC-16-041) Pending
Solid State Heating and Cooling	Radiant Systems for Energy Efficiency and Comfort (EPC-14-009)	No current or planned investments
Heat Pumps	Low Cost, Large Diameter, Shallow Ground Loops for Ground-Coupled Heat Pumps (EPC-15-019)	No current or planned investments

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

The proposed initiatives will develop and test advanced HVAC technologies and controls to improve performance and cost-effectiveness, and move them closer to deployment and commercialization. The initiatives focus on testing and demonstrating advanced high-efficiency electric HVAC and refrigeration systems that provide the same or better performance and operational cost as natural gas fired systems. The demonstrations should look at a mix of building types – single family residential, multifamily, small commercial, and large commercial – across various climate zone and IOU service areas.

Develop and test emerging HVAC and refrigeration systems and controls

Emerging HVAC systems, such as direct current compressors, cold climate heat pumps, and electrochemical compressors are needed because of the potential performance/energy savings over conventional equipment and environmental issues with current refrigerants. There is also a need to move toward low- or zero GWP and ozone depletion potential (ODP) refrigerants and to focus on HVAC systems that are suitable for all climate zones while keeping high efficiency.

Improve materials and manufacturing processes to overcome current limitations in HVAC systems

Heating and cooling systems depend on “heat exchangers” that transfer heat from the surfaces of the equipment, usually metal surfaces, to air. Efficient heat exchangers are typically large and expensive. New manufacturing methods including additive manufacturing, may allow production of heat exchange designs not possible with traditional approaches, which could increase the efficiency of commercial air conditioners by as much as 20 percent.[36]

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36 Based on prototype heat exchanger requirements specified in a US DOE research grant: https://aquicore.com/blog/3d-printing-heat-exchangers/

Initiative 1.3.1 Develop and Test California Climate Appropriate Electric Heat Pump Space and Water Heaters

Description	In recent years, manufacturers have designed electrically-driven heat pumps for cold-climate operation through the use of multi-stage, variable-speed, or booster compressors, advanced refrigerant management, improved defrost control, alternative refrigerants, and other features. This initiative will develop and test advanced electric California climate appropriate heat pumps for space and/or water heating that can perform at low-ambient temperatures without affecting performance, energy efficiency or operating costs. Potential areas of consideration include elimination of defrost (or frost buildup) and backup heat sources to improve the performance and energy efficiency of cold climate heat pumps. The prototype heat pump to be developed for space conditioning must have an HSPF ≥ 12/≥ 27.5 SEER (including fan energy). Coefficient of Performance (COP) ≥ 3.2 (at 5 degrees F and maximum capacity) and for water heating the average COP ≥ 4 as measured in the laboratory and in actual installations. The prototype would be tested in a mix of building types, such as single-family, multifamily, and small commercial buildings across various California climate zones (hot and cold climates) and IOU service areas.
Impact if Successful	Incorporating advanced compressor designs, defrost techniques, and other features improves the performance of cold climate heat pumps beyond previous products. This improvement could result in reducing operating costs and increase consumer interest in purchasing and using electric heat pumps for space and water heating.
Primary Users and/or Beneficiaries	Residential and commercial building owners, equipment manufacturers, HVAC contractors
Metrics and Performance Indicators	Efficiency (energy savings compared to standard heat pumps), satisfactory performance based on occupant surveys.
Topic(s) addressed	Technical and Cost Advancements
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development

Initiative 1.3.2 Develop and Test Electrochemical Compression Systems

Description	Mechanical compressors in cooling equipment are very energy-intensive and have an efficiency around 65 percent. In place of a noisy motor-driven compressor, electrochemical compressors can improve the efficiency by about 30 percent. Hydrogen gas combines with water, ammonia, or another refrigerant and drives the combined working fluid through a standard vapor-compression cycle. The research would develop and test a working prototype in a California light commercial building and document the energy savings over a year of monitoring. Data will be collected on performance, savings, and operations over various load conditions. Eventual use could be residential and light commercial HVAC systems (including split systems, heat pumps and packaged systems) and refrigerators and could be expanded to larger systems.
Impact if Successful	If successful, lightly pressurized hydrogen can be produced from electricity driving an HVAC cycle with water, leveraging the excellent thermodynamic characteristics of hydrogen as well as existing proton-exchange-membrane technology. If successful, this initiative would introduce HVAC products using electrochemical compressors. Electrochemical compressors have no moving mechanical parts, are solid state, are silent, use hydrogen as the refrigerant, use about 30 percent less electricity than mechanical compressors, and compresses hydrogen without significantly heating.
Primary Users and/or Beneficiaries	Residential and commercial buildings, refrigerated warehouses, refrigeration and HVAC manufacturers
Metrics and Performance Indicators	The COP of an electrochemical compression systems ≥ to 4.5
Topic(s) addressed	HVAC Designs
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development Technology Demonstration and Deployment

Initiative 1.3.3 Manufacturing and Designing Improved Heat Exchangers

Description

Heating and cooling systems depend on heat exchangers to transfer heat from the surfaces of the equipment to air. Efficient heat exchangers are typically large and expensive. It may be possible to greatly improve heat exchange efficiency through improved designs such as use of microchannel devices. New manufacturing methods including additive manufacturing may allow production of heat exchange designs not possible with traditional approaches, which could increase the efficiency of commercial air conditioners by as much as 20 percent.

Additive manufacturing may also contribute to energy efficiency across sectors, whether through the rapid development and fabrication of prototypes to reduce the cost and lead time of new products or more directly through the production of energy-saving products, such as compact, high-surface area heat exchangers (condensers and evaporators) that are more efficient than heat exchangers made by conventional methods. Additional HVAC products could include enclosures, fan shrouds, heat pipes and even fan blades. Three-dimensional printing will allow for customization of air conditioning systems, which is not cost-effective using traditional manufacturing. This initiative proposes a design competition for developing heat exchangers for various applications (condensers and evaporators) and must include the following requirements:

- A new design heat exchanger must have efficiency greater than 20 percent compared to current "best available" heat exchangers. When installed into an electric heat pump, the resulting SEER must be ≥ 23.5.
- New design must be cost competitive.
- The new design must meet required performance and durability requirements.
- The designer must have a manufacturing partner, such as an HVAC manufacturer. Researchers can use various additive manufacturing technologies to include 3D Printing, Rapid Prototyping (RP), Direct Digital Manufacturing (DDM), layered manufacturing, and additive fabrication to develop prototype heat exchanger units. The selected design winner will receive funds to build a prototype and incorporate it into an electric heat pump. The heat exchanger will be

evaluated for efficiency, performance and durability for a minimum of 12 months.

Impact if Successful	If successful, innovative heat exchanger designs for HVAC systems may reduce the volume and weight of heat exchangers and improve performance up to 20 percent.
Primary Users and/or Beneficiaries	HVAC manufacturers
Metrics and Performance Indicators	Efficiency—energy savings and efficiency and performance improvements, high level of acceptance by other manufacturers, reduction in weight
Topic(s) addressed	HVAC Designs
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development

Table 7: Ratepayer Benefits Summary For Sub-Theme 1.3

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 1.3.1 Develop and Test California Climate Appropriate Electric Heat Pump Space and Water Heaters				X	X				
Initiative 1.3.2 Develop and Test Electrochemical Compression Systems				X	X				
Initiative 1.3.3 Manufacturing and Designing Improved Heat Exchangers		X		X	X		X		

Source: California Energy Commission

1.4 Enable Integration of Building and Equipment Controls and Automation

Building Control and Automation represents one of the most innovative opportunities to reduce electric consumption in buildings and electricity demand in California.[37] Advanced building controls can optimize the balance between user comfort and energy savings. In addition, these control systems can also provide grid support through means such as demand response, and act as a distributed energy resource when storage and renewables are incorporated.

Some of the key activities in this area have been the creation of various open standards such as the Building Automation and Control network (BACnet), Open Automated Demand Response (OpenADR), Open Home Area Networks (OpenHAN), Open Advanced Metering Infrastructure (OpenAMI), and Utility Advanced Metering Infrastructure (UtilityAMI). Progress in regulations and standards has also been made such as the adoption of automation and smart technology in standards such as Title 24 (California Building Code), and ASHRAE 90.1 (National Energy Code). Low power communication technologies (LiFi, ZIGBEE, Bluetooth low energy) and new wired solutions such as Power over Ethernet (PoE) are also available.

Due to large energy needs and economies of scale, building automation is most developed for large commercial and industrial buildings. There are three fundamental technical and market drivers: the concept of integration and interoperability, the growth of Internet Protocol (IP), and, the "open" influence on physical systems. For example, HVAC systems could be designed differently when the ability to automate is considered. From the operational side, drivers include financial pressures to contain costs and improve operating efficiencies, the rising cost of energy and maintenance, and the need to maintain occupant comfort.

DOE has recognized small- and medium-scale building automation as a large opportunity for future development stating, "In 2012, about 70 percent of commercial buildings larger than 100,000 square feet, for example, had some kind of energy management or control system for HVAC, but only about 15 percent of buildings smaller than 25,000 square feet used them."[38]

There are several opportunities for development in small and medium-size scale markets. These opportunities include the use of smartphones and other forms of granular data (photo-sensing, GPS location, and others) to enable a more intentional and targeted use of building systems, such as lighting, heating, and other energy-intensive services. This evolving connectivity of consumer devices provides opportunities to tap into human behavior cues and optimize energy usage in a building while moving away from the centrally controlled building management paradigm.

Additional opportunities exist by targeting the complexity of current building

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37 *Building Control and Automation* refers to but is not limited to: Building Automation and Control Systems (BACS), Building Control Systems (BCS), Building Automation Systems (BAS), Building Management Systems (BMS), and Smart Buildings and/or the Internet of Things (IoT).

38 Department of Energy, Quadrennial Energy Review Transforming the Nation's Electricity System: The Second Installment of the QER. 2017 https://www.energy.gov/sites/prod/files/2017/02/f34/Quadrennial%20Energy%20Review--Second%20Installment%20%28Full%20Report%29.pdf

management systems. Typically, systems require complex and expensive solutions to produce effective interoperability. However, scalable cost-effective solutions for building automation in medium and small commercial buildings or in buildings with existing controls will increase the return on investment for deployment of intelligent building controls. If these areas are addressed and successful in smaller buildings, that knowledge can be expanded to larger buildings and provide additional value to the invested EPIC funds.

As intelligent building automation and controls become prevalent across a more diverse range of building, California's building stock can provide grid support by becoming a flexible resource.

Earlier EPIC research has included a number of applied research projects focused on building automation enabling technologies. Those include (1) low-cost air flow sensors to diagnose wasteful HVAC malfunctions; (2) low-cost "smart" thermostats with simple user interface that do not need broadband and that can be deployed in low-income, multifamily buildings; (3) low-cost lighting components with open communication interfaces for seamless integration into whole building control and automation systems; (4) integration of "smart" fans and thermostats for low-income properties in disadvantaged communities; and (5) integration of controls for lighting, fenestration, and HVAC systems with improved sensors.

These technologies are under development and testing for eventual installation in buildings and facilities. The goal of these projects is to find low cost and simple solutions for controlling HVAC or lighting systems, reduce the need for space conditioning, or improve sensors to result in better building control of lights and HVAC systems.

In 2017, the Energy Commission funded, under EPIC, a series of control projects that integrated multiple energy systems. These demonstration projects focused on technologies that can continuously optimize the management of building sensors for major energy-consuming devices and integrated control strategies for lighting, plug-load controls and HVAC systems. The goal of these projects is to demonstrate an average potential of 20 percent energy savings in affected buildings, which total about 1.6 million square feet.

KEY TECHNICAL AND MARKET CHALLENGES

Over the last several decades, building energy controls and automation have evolved rapidly, with new technologies, data sources and capabilities available at lower cost. Remaining challenges are described below.

Proprietary standards and closed ecosystems

Proprietary standards and closed ecosystems have resulted in inflated fixed costs associated with the integration of advanced smart building controls (for example, sensors, controllers, software) in the residential and small- to medium-sized commercial markets. For example, proprietary wireless communication protocol stacks such as ZigBee, Bluetooth, and Wi-Fi tend to be incompatible with each other at a device level and rely on additional connecting devices to link together the data sources. Proprietary controllers, some designed with limited controls and no interoperability, do not integrate well with packages from other vendors, cooperation is usually only at a high-level rather than a device level. This fragmentation affects the return on investment and adoption of advanced building control technologies.

Moreover, smart building controls have not increased the value of buildings even though they provide qualitative and quantitative benefits. Through the use of more advanced evaluation, measurement, and verification (sometimes referred to as EM&V 2.0) stakeholders can better evaluate energy efficiency programs and incentives, improving their effectiveness and enabling energy efficiency providers to more accurately monetize energy efficiency benefits and capture additional value in the marketplace.

Expanded application of human-centered design thinking

Although some building efficiency research incorporates human-centered design thinking, further work is needed to identify new opportunities to achieve greater energy savings while meeting occupants' needs. Research has looked at providing targeted space conditioning at an individual level, human interaction with efficiency technologies and efficiency cues to name a few. There is a need to further investigate how incorporating human needs and tendencies into early stage building design through innovative controls, automation and other means could help expand the adoption of building control and automation technologies.

Digital privacy and security standards

Comprehensive standards and protocols have yet to be fully developed and vetted in the evolving landscape of building automation. There are many private interests in creating proprietary solutions and many of these exist today, but without public research into open standards and protocols, costs associated with building digital privacy and security will remain inflated. Further development is critical to expand cost-effective solutions and to increase adoption of automated building energy management solutions. Due to complexities involved such as differing needs and priorities of stakeholders, and the sheer volume of devices involved in a building automation network, creating comprehensive open standards and protocols has been a major challenge.

Table 8: Previous and Planned EPIC Investments on Automated Controls

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Easy and Economic Integration of Building Automation and Control Technologies	Low-cost Ultrasonic Anemometer for Use Indoors and in HVAC Ducts (EPC-14-013) Intelligent HVAC Controls for Low-Income Households (EPC-15-020) Flexible, Networked Lighting Control Systems That Reliably Save Energy (EPC-14-017)	Integrating Smart Ceiling Fans and Communicating Thermostats (EPC-16-013) Pilot-scale Evaluation of Integrated Building Control Retrofit Package (EPC-16-003) Automated Cloud-Based Continuously Optimizing Building Energy Management System (EPC-16-034)-Pending Internet of Things and Ubiquitous Sensing in University Building Energy Management (EPC-16-033) – Pending Leading Los Angeles: Demonstrating Scalable Emerging Energy efficient Technologies for Integrated Façade, Lighting and Plug Loads (EPC-16-032) – Pending
Using Machine Learning and Human Centered Design Thinking to Increase the Effectiveness of Advanced Building Controls and Automation	Workstation Controls and Strategies for Personal Comfort Systems (500-08-044)	No Current or Planned Investments
Digital Privacy and Security Standards in Advanced Building Automation and Control Technologies	No Projects	No Current or Planned Investments

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

Building automation, the Internet of Things, transactive energy, behavioral science, and artificial intelligence have the combined potential to revolutionize the building industry by creating a robust, flexible network capable of performing as a distributed resource while providing occupant comfort and energy efficiency. Investments in these areas will foster workforce development and increased energy reliability for future generations and address some of the major challenges facing widespread adoption of building automation systems.

Initiative 1.4.1 Research and/or Demonstrate Standardized Platforms, Protocols, and Interoperability of Technologies

Description	This initiative will investigate the feasibility of new open standards or new implementations based on existing efforts that can create affordable, flexible building automation solutions across small and medium scale building types (for example, small commercial and residential). Research may include advancements in standardized controller technologies (i.e., HVAC controllers), demonstration of open standard communication protocols, or the development of open standard protocols for smart phone, tablets, or other granular data source communication for building energy systems.
Impact if Successful	Standardized platforms could accelerate technology adoption by providing industry vetted and accepted means for implementing building automation systems. These industry-accepted standards could be used as reference points for research and development projects and utility incentive programs. By providing open standards and protocol stacks, vendors will not have to build their own communication and control systems, significantly reducing the development costs and time needed to incorporate automated control functionality into their products. The open standard would also enable interoperability, meaning equipment from multiple vendors could communicate with little to no additional setup costs or specialized installation needed. This not only lowers the installation costs of automated technologies in buildings, it gives customers the flexibility to change equipment providers. Because of the advantages of the open standard, building automation in small and medium scale buildings will be able to scale much quicker and cheaper than if private companies had developed proprietary automation controller and systems.
Primary Users and/or Beneficiaries	Building owners, building developers, building occupants

Metrics and/or Performance Indicators	Consolidation of existing and new standards by the building energy management system controls companies, market penetration rate of new technologies into various building sectors, energy savings
Topic(s) addressed	Integration of Building Automation and Control Technologies
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development Technology Demonstration & Deployment

Initiative 1.4.2 Human Centered Design Thinking for Next Generation Building Controls

Description	Human-centered design thinking in the engineering and implementation phases of building automation technologies can identify opportunities for energy savings while maintaining comfort. Dynamic, simulated environments that enable building designers to interact with representative occupants early in the design process can help ensure the occupant's needs are met in an intuitive and appealing way. Furthermore, the use of smartphones and other solutions with machine learning can connect human and building needs to evolving building automation capabilities but requires further investigation.
Impact if Successful	Building automation systems will perform better and stakeholders such as building owners and occupants will gain more value from a well-designed, smart building automation system. Furthermore, there will be benefits such as increased occupant comfort, reduced maintenance and energy savings.
Primary Users and/or Beneficiaries	Building owners, building developers, building occupants
Metrics and Performance Indicators	Return-on-investment for building automation technologies, energy savings
Topic(s) addressed	Machine learning and human centered design
Value Chain	Demand-side Management
Program Area(s)	Technology Demonstration and Deployment Market Facilitation

Initiative 1.4.3 Demonstrate Innovative Security and Cybersecurity Methods

Description	There are real risks associated with security threats to buildings with the use of building automation systems. This initiative aims to research existing or novel approaches to securing technologies that promote the interactions between users, buildings, and the grid. Research can range from demonstration of building transactive energy models and tokenization of energy, to demonstration of block chain security, or digital privacy and security standards such as The Digital Standard.
Impact if Successful	By promoting novel security and energy transaction approaches such as blockchain this initiative will help demonstrate how buildings and grid can interact in a highly secure manner while providing privacy, transactional integrity and financial security for the users and promoting a prosumer approach to grid interactions from a building perspective.
Primary Users and/or Beneficiaries	Building owners, building developers, building occupants, building energy management system control companies, utilities
Metrics and Performance Indicators	Grid and building flexibility and reliability, energy savings, adoption of privacy and security standards.
Topic(s) addressed	Privacy and Security Standards
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development

Table 9: Ratepayer Benefits Summary For Sub-Theme 1.4

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 1.4.1 Research and/or Demonstrate Standardized Platforms, Protocols, and Interoperability of Technologies		X	X					X	X
Initiative 1.4.2 Human Centered Design Thinking for Next Generation Building Controls		X		X				X	
Initiative 1.4.3 Demonstrate Innovative Security and Cybersecurity Methods			X					X	

Source: California Energy Commission

1.5 Increase Plug Loads and Consumer Electronics Efficiency

Plug loads are the fastest growing category of energy use homes and businesses. Plug loads – energy consumed by devices that are plugged into power outlets – are second only to HVAC in terms of residential energy use. Electronic products such as computers, televisions, internet networking devices, household appliances, and miscellaneous devices such as vacuums, power tools, and battery chargers all fall into this category. Controlling these loads is important for meeting California's ZNE and SB 350 building efficiency goals. Lighting and HVAC have become efficient and building envelopes have become tighter; however, plug loads, many of which are not regulated, are estimated to be 40 percent of the electrical load of a building. Improvements are needed to improve device efficiency and increase adoption – through codes and standards as well as accelerated technology evolution and changes in end-user behavior. These standards and behavioral changes have the potential to shift the marketplace toward more efficient products and practices, providing significant savings to California consumers.

"THE U.S. ENERGY INFORMATION ADMINISTRATION (EIA) PROJECTS PLUG LOAD END-USES TO BE THE FASTEST GROWING ENERGY END-USE"
AMERICAN COUNCIL FOR AN ENERGY-EFFICIENT ECONOMY[39]

Early Energy Commission R&D efforts gathered data on plug-in devices by assessing the energy use of office electronics, flat-screen TVs, home stereo/audio systems, 24/7 kiosks, and multi-media computers. Research improved efficiency of stand-alone devices such as set-top boxes, computers, and external battery chargers and power supplies.

Some of these efforts informed the State of California's Title 20 appliance efficiency standards and resulted in more efficient devices, such as the external volt power supply standard, TV standard, and the battery charger standard.

"ALWAYS-ON BUT INACTIVE DEVICES MAY COST AMERICANS $19 BILLION AND 50 POWER PLANTS' WORTH OF ELECTRICITY ANNUALLY"
NATIONAL RESOURCE DEFENSE COUNCIL[40]

In recent years, the Energy Commission's R&D included projects to reduce or eliminate standby energy use through plug-load management such as developing and testing technology that incorporates mobile power management. This also includes new power management interfaces for desktop computers, energy reporting, and mobile applications that enables users to identify idle loads. Also, the Energy Commission has funded projects to develop new energy-efficient devices for appliances in food service, ZNE buildings, and electronics such as gaming consoles.

Challenges affecting further efficiency of plug loads are described below.

KEY TECHNICAL AND MARKET CHALLENGES

The market for plug-in devices evolves quickly. Consumers now have more devices in their homes than they did 20 years ago. These devices have more functionality and capabilities than similar devices even a decade ago.

39 American Council for an Energy Efficiency Economy, *Miscellaneous Energy Loads in Buildings* June 2013

40 National Resource Defense Council,*Home Ide Load: Devices Wasting Huge Amounts of Electricity When Not in Active Use* May 2015

On average, California households have 50 electronic devices, appliances, and other miscellaneous electric loads.[41] When federal standards exist for a particular product type, California is pre-empted from setting more stringent efficiency standards. To achieve greater efficiency from the growing number of consumer devices, the following barriers need to be addressed:

Reduce the cost of power management capability for consumer devices

The Natural Resources Defense Council (NRDC) conducted a small sample study of households to document device ownership and measure associated energy use.[42] The study found that many consumer devices lack any power management capabilities. For consumer electronics, appliances and devices that are not pre-empted by federal regulations, research is needed to advance power management technology that does not add to manufacturing costs, does not affect the consumer's experience using the device, and documents the energy-saving benefits.

Additional research is needed to create a larger, representative dataset on power management practices across non-pre-empted devices from which reliable estimates of ownership and potential energy savings can be made. Such data can help identify energy-saving opportunities and potential for research to improve cost-effectiveness. The results of this research can inform development of future Title 20 appliance efficiency standards.

Demonstrate more efficient emerging technologies in the consumer device sector that are not pre-empted by federal standards

Large-scale energy efficiency demonstrations can provide data for development of Title 20 appliance efficiency codes and standards. Improvements have been made on the power management of computers but need to be demonstrated at computer labs, offices, and schools. Plug-load and control strategies are being addressed but lack market adoption. Also, these types of demonstrations will educate consumers and building operators and document the costs and benefits associated with implementing more efficient plug-load technologies. In addition to energy savings, demonstrations can document other benefits such as security and improved data management.

Develop strategies that address Internet of Things (IOT) devices and idle loads

Many devices in homes and businesses are left on 24/7. Some of these devices include networking devices (modems, routers, servers), medical equipment (heart monitors), hardwired equipment (burglar alarms, garage door openers, ground fault circuit interrupters, doorbells, sprinkler systems), and imaging equipment (printers, scanners, copiers). Some of these devices have low power and idle modes but still consume energy 24/7. Devices such as networking equipment do not typically have power management modes. Technical capabilities for power management are available in some plug-load devices such as mobile phones, but these have yet to be implemented in many plug-in devices. Research is needed to identify why power management technologies have not been more broadly implemented, to determine cost-effective solutions and to test various strategies to document benefits. The goal is

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41 National Resource Defense Council, "Plug-In Equipment Efficiency: A Key Strategy to Help Achieve California's Carbon Reduction and Clean Energy Goals" April 2015 https://www.nrdc.org/sites/default/files/home-idle-load-plug-in-efficiency-IB.pdf

42 National Resource Defense Council, *Home Idle Load: Devices Wasting Huge Amounts of Electricity When Not in Active Use.* 2015. https://www.nrdc.org/sites/default/files/home-idle-load-IP.pdf

to shift industry practice and improve the
efficiency of IoT devices during idle modes.

Table 10: Previous and Planned EPIC Investments on Plug Loads and Consumer Electronics Efficiency

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Consumer Electronics	Mobile Efficiency for Plug Load-Devices (EPC-15-021) Gaming System Energy Efficiency without Performance Compromises (EPC-15-023)	No current or planned investments
Building Appliances	Plug Load Savings Potential of Commercial Foodservice Equipment (EPC-15-027)	No current or planned investments
Power Conversion	Efficient and ZNE-Ready Plug Loads (eliminate standby power-reconfigure for DC power) (EPC-15-024)	No current or planned investments
Plug load Management	Unlocking Plug Load Energy Savings through Energy Reporting (energy reporting and control signals for multiple devices (EPC-15-026) Power Management User Interface for computers (EPC-15-022) Flexible Control Strategies for Plug Loads with Context-Aware Smart Power Outlets to Mitigate Electricity Waste and Support Demand Response (EPC-15-031) Plug Load Reduction App to Reduce Home Idle Loads With Smart Meter Analytics (EPC-15-025)	No current or planned investments

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

The Energy Commission's initiatives address key market challenges to increase efficiency of plug load devices and provide device data that can help inform future Title 20 appliance efficiency codes and standards. Because technology advances occur quickly, close communication with industry stakeholders is critical to direct research where it is most relevant and needed. These initiatives will focus on cost-effective technologies and strategies with a high potential for energy savings while minimizing impacts to consumers.

Initiative 1.5.1 Develop and Test New Strategies for Low Power and Idle Mode Devices

Description	This initiative will address devices, including networks that are always on but have low power/idle mode or no power management capabilities. These modes consume electricity even when the owners are not using them or think they have been turned off. This research will: • Identify and rank products with the highest potential of energy savings and develop a comprehensive database of device ownership, usage patterns (duty cycles), and energy consumption • Develop test procedures for measuring idle mode and active mode that could help inform future codes and standards • Develop and test devices that have zero to near zero idle modes that do not affect the quality of the device or the main functionality and that could be added to the high-ranking devices at little or no additional cost. The test could involve various end user groups and collect data on pre- and post-efficiency practices. • Develop effective strategies that will motivate manufacturers to include them in the design methodology, such as power management, sensors and controls
Impact if Successful	Results from projects funded through this initiative could lead to more energy efficient and reliable devices out in the marketplace. These types of devices can influence future Title 20 appliance efficiency codes and standards. If implemented through manufacturers, this initiative could lower energy bills for consumers.
Primary Users and/or Beneficiaries	Electronic manufactures, consumers, building owners, IOUs, governmental codes and standards setting agencies
Metrics and/or Performance Indicators	Energy savings, greater reliability, number of manufacturers adopting technology.
Topic(s) addressed	Plug-load devices
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development

Initiative 1.5.2 Develop and Test Energy Saving Opportunities for Electronic Medical Equipment With Potential to Reduce Standby or Idle Energy Use

Description	This initiative will address energy-saving opportunities for medical equipment in the healthcare sector. Hospital managers often lack measured energy use data on their facilities and most decisions on energy efficiencies are often based on building simulation modeling. The National Renewable Energy Laboratory (NREL) completed a study of plug-load usage in hospitals. In particular, one of the areas studied was hard-wired, medical imaging devices, such as MRIs, and CAT Scans. These devices are on 24/7 and even when they are not used, the idle modes show that these devices could use up to 10 kilowatts (kW). This research will examine medical equipment plug-load operational modes to determine control technologies/strategies to power down devices when not in use, and reduce idle power while ensuring fast response and emergency readiness. This research will: • Identify and rank hospital/home/office medical equipment with the highest potential of energy savings by end use sector. Examples of equipment could include heart monitors, MRI scanners, CAT Scans, X-Rays, and other lab equipment create a database of device ownership, usage patterns (duty cycles) and energy consumption • Work with a manufacturing partner and other stakeholders (for example, hospitals, and the California Office of Statewide Health Planning and Development) to develop and test devices that have control strategies to reduce idle power or power down devices when not in use, such as on weekends in a medical office, but maintain functionality and fast response for emergency readiness. • Develop effective strategies that will motivate manufacturers and the healthcare industry to include control strategies in the design methodology
Impact if Successful	This initiative if implemented can save money and energy to California residents and the healthcare industry
Primary Users and/or Beneficiaries	Hospitals, healthcare industry, equipment manufacturers, government, IOUs

Metrics and Performance Indicators	Lower energy bills, adoption of features by manufacturers, acceptance of new devices by healthcare professionals, approval by medical care regulators
Topic(s) addressed	Plug-load devices
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development

Initiative 1.5.3 Large-Scale Demonstrations of Low Energy Consuming Plug-In Devices With High Potential for Market Adoption and Penetration

Description	This initiative will demonstrate emerging, low-energy consuming plug-load technologies with at least 10 percent less energy consumption than devices on the market. These technologies must have high technical potential, add minimally to equipment cost and have near term applicability. The demonstrations can provide a foundation for both scaling up production and providing the energy data to justify savings and benefits.
Impact if Successful	Results will have the potential to influence future Title 20 codes and standards, and the potential for substantial savings in both the commercial and residential sectors.
Primary Users and/or Beneficiaries	Building owners and operators, end-users, and IOUs
Metrics and Performance Indicators	Lower energy bills
Topic(s) addressed	Plug Load devices and Strategies
Value Chain	Demand-side Management
Program Area(s)	Technology Demonstration and Deployment

Table 11: Ratepayer Benefits Summary For Sub-Theme 1.5

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 1.5.1 Develop and Test New Strategies for Low Power and Idle Mode Devices	X	X					X		
Initiative 1.5.2 Develop and Test Energy Saving Opportunities for Electronic Medical Equipment with Potential to Reduce Standby or Idle Energy Use	X	X		X			X		
Initiative 1.5.3 Large-Scale Demonstrations of Low Energy Consuming Plug-In Devices with High Potential for Market Adoption and Penetration	X	X					X		

Source: California Energy Commission

1.6 Transitioning to Direct Current Powered Buildings

California is leading the way in the United States in the deployment of rooftop solar, adoption of electric vehicles, and the promise of distributed battery energy storage in homes and buildings. While these technologies all use Direct Current (DC), they are not completely unique. Many of the electrical loads commonly used in buildings, including LED lighting and consumer electronics, are increasingly powered by DC. However, electrical distribution systems in California's new and existing buildings are almost exclusively Alternating Current (AC).

The increased market penetration of DC load electronics requires the use of dedicated rectifiers to convert the supplied AC to the needed DC, increasing the device cost and adding energy inefficiencies. Coupling these losses with the need to invert power produced by distributed, renewable energy resources, such as rooftop solar, from DC to AC, introduces significant losses. Experimental results show energy savings in the 4 to 8 percent range, with the potential for energy savings in the range of 10 to 20 percent with advancements in power electronics, smart implementation, and efficiencies realized through implementation.[43,44]

Turning these losses into energy savings and incorporating DC electrical system into the California's building practices and building code will support California's push towards newly constructed, ZNE homes by 2020 and ZNE commercial buildings by 2030. More benefits could be realized by bringing the control capabilities that come from core DC power technologies, such as USB and Power over Ethernet (PoE), to better manage building power loads for efficiency, to build a robust Internet of Things, and to support grid needs.

KEY TECHNICAL AND MARKET CHALLENGES

Considerable momentum is needed to overcome the status quo of AC buildings distribution systems and incorporate DC into construction practices when appropriate. Transforming building systems and end uses to DC and hybrid AC/DC systems has many technical and market challenges, such as proving the benefits of DC and hybrid buildings, developing standards, training workforce, and expanding availability of consumer products designed for DC systems. Overcoming these barriers to access efficiency benefits and increased energy management potential of DC and hybrid buildings will help drive the next generation of ZNE buildings in California and provide the information necessary to make DC and hybrid buildings commonplace in new construction.

Providing the Benefits of DC and Hybrid Buildings

A key challenge to DC distribution system adoption is the insufficiently quantified benefits of DC electrical systems. Quantifying cost and energy savings, load controllability, and non-energy benefits of DC systems will assist in transitioning to DC and hybrid buildings in certain applications.

A Need for Standards

Without industry standards for DC distribution infrastructure, builders will hesitate to consider DC systems as a main

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43 Johnson, K. et al, *Direct Current as an Integrating Platform for ANE Buildings with EVs and Storage: DC Direct Systems – A Bridge to a Low Carbon Future?* http://aceee.org/files/proceedings/2016/data/papers/10_780.pdf

44 Pantano, S., et al, *Demand DC: Adoption Paths for DC Power Distribution in Homes*, http://aceee.org/files/proceedings/2016/data/papers/1_156.pdf

stream option. Developing industry standards will give manufacturers and consumers' confidence in potential markets for DC systems and appliances. Establishing standards will create a structure for safe DC building implementation and drive innovation by assuring competition and stability for early investments.

Workforce Training

Implementing DC systems in California buildings will require a workforce that is prepared to shift from installing AC electrical systems to installing DC electrical systems. Though there are a handful of electrical contractors qualified to install DC wiring in buildings, this knowledge is not wide spread. Preparing the workforce to incorporate DC electrical systems in buildings will require the development of best practices and installation manuals. These manuals will be foundational to the successful implementation of efficient DC systems in buildings.

Direct DC Consumer Electronics

Many consumer electronics use DC power converted from AC at the plug. However, DC to AC conversion losses could be eliminated if electronics such as LED lights and electric vehicles (EVs) were connected to a DC power source. Large appliances, such as space heating and cooling systems, refrigerators and freezers have components that can run on DC power but currently rely on AC power. Transitioning these key components to accept both AC and DC power and establishing small scale demonstrations in niche markets, such as mobile or manufactured homes, could quantify the costs and benefits of these hybrid components. Hybrid components require further research with respect to technical/economic feasibility, efficiency and cost competiveness when compared to equivalent AC load components. Driving efficiency up and costs down for these components could increase consumer understanding of the benefits of DC buildings and create markets and demand for further development.

Table 12: Previous and Planned EPIC Investments on Direct Current Research

Topics	2012-14 Investment Plan	2015-17 Investment Plan
DC Architecture and Demonstrations	Direct Current as an Integrating and Enabling Platform (EPC-14-015) A Renewable Based Direct Current Building Scale Microgrid (EPC-14-053)	No current or planned investments
DC Workforce Training	No projects	No current or planned investments
DC Standards	No projects	No current or planned investments
DC Appliances	No projects	No current or planned investments

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

The funding initiatives under this theme aim to test DC systems in various configurations for different buildings to increase confidence in and understanding of DC systems for California's industry, workforce, and consumers. This will be achieved by evaluating safety protocols, establishing best practices, developing industry standards for DC systems, and broadening the availability of efficient DC appliances. Successful projects under these initiatives will provide valuable information on the capabilities of DC electrical systems in buildings, drive inclusion of DC systems in new building construction, and provide market assurance for innovators, manufacturers, and consumers.

Initiative 1.6.1 DC Building Distribution Systems to Enable ZNE Buildings by 2030

Description	This initiative will support the development of DC buildings, and hybrid AC/DC buildings, and develop a test bed that can be used to demonstrate electrical components and configurations, system voltages, communication protocols, installation procedures, and safety protections necessary for standards and to inform Title 24 buildings standards for DC and hybrid buildings. The test bed will determine the optimal combinations of AC and DC electrical systems in different building types to maximize the energy efficiency, power quality, resiliency, cost, occupant control, and other non-energy benefits in both the residential and commercial sectors, while comparing the benefits of DC and hybrid buildings to traditional AC buildings. The test bed will also explore the technical feasibility, cost, and safety of repurposing existing AC systems into DC systems. Testing and demonstration will include evaluating operations of DC systems that incorporate roof top solar, electric vehicle charging, customer-side energy storage, and building control systems and integration with USB and Power over Ethernet (PoE) devices. This test bed will provide DC appliance manufacturers with opportunities to test their products in a DC building environment. This will provide valuable, practical information to appliance manufacturers on how their appliances will function in actual DC buildings and inform engineers on the impacts the operation of different appliance will have on DC building systems. Work done in this test bed will help establish best practices for DC systems and feed into training materials on how to design, install, and maintain effective DC electrical systems in buildings.

Impact if Successful	A successful DC and hybrid building test bed will provide consumer protection and facilitate the stronger market for DC technologies necessary for mass adoption. Successfully quantifying the cost, operational, energy and non-energy benefits of DC buildings through demonstration will provide the building industry, and individual consumers, with valuable information on DC and hybrid buildings and could motivate businesses and other organizations to accept potentially longer payback periods, accelerating adoption of these advanced technologies. As markets for PV and battery storage systems grow, stimulated by anticipation of NEM 2.0, the benefits of DC and hybrid buildings could promote greater adoption of PV, battery storage systems, and electric vehicles.
Primary Users and/or Beneficiaries	Electric ratepayers who own and operate buildings, construction industry, electrical contractors, appliance manufacturers, energy regulators, HVAC equipment manufacturers and installers, building designers, academia, researchers, utilities, solar installers, inverter manufacturers, battery energy storage industry, and building retrofitters.
Metrics and/or Performance Indicators	Development of cost comparisons for DC buildings, AC buildings, and hybrid buildings, data to inform future Title 24 development, best practices and training materials that for installing DC and hybrid electrical systems in buildings.
Topic(s) addressed	DC Buildings, Industry Standards, DC appliances, Workforce Training
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development Technology Demonstration and Deployment

Initiative 1.6.2 Direct DC Power Consumption of Native DC Electronics and Development of Cost Competitive, Efficient Hybrid AC/DC Appliances

Description	This initiative will explore the energy benefits of directly connecting native DC electronics to DC power and develop and test cost-competitive hybrid components in targeted markets. Potential hybrid components can include motors, variable frequency drives used in space heating and cooling systems, refrigerators and other appliances. The development and testing of these hybrid components in targeted markets will document efficiency gains, cost savings, benefits and other considerations with respect to DC electronics and appliances.
Impact if Successful	This initiative could lead to greater adoption of DC appliances and DC buildings by decreasing the initial purchase price and lowering the lifetime energy costs.
Primary Users and/or Beneficiaries	Electric ratepayers with DC systems in their buildings, appliance manufacturers, energy regulators, HVAC equipment manufacturers and installers, academia, researchers, utilities
Metrics and/or Performance Indicators	Lower cost primary components for DC appliances, number of manufacturers producing DC appliances, number of new DC appliances being offered in the marketplace.
Topic(s) addressed	DC appliances
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development

Table 13: Ratepayer Benefits Summary For Sub-Theme 1.6

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 1.6.1 DC Building Distribution Systems to Enable ZNE Buildings by 2030	X	X			X		X		
Initiative 1.6.2 Direct DC Power Consumption of Native DC Electronics and Development of Cost Competitive, Efficient Hybrid AC/DC Appliances	X	X			X		X		

Source: California Energy Commission

1.7 Enable Cost-Effective De-carbonization of California's Industrial Sector

The industrial sector in California uses roughly 24 percent of the electricity and more than 38 percent of natural gas consumed annually. This sector is vital to California's economy and depends on affordable, reliable, and sustainable energy supplies. Major industries in California include metal smelting and recycling, light manufacturing, plastics, pharmaceuticals, plating, and petroleum products, among others. Some industries, such as plastics, smelting, and glass manufacturing, depend heavily on natural gas to operate furnaces, boilers, and kilns for manufacturing products. These industries use electricity primarily for operating fans, pumps, motors, compressors, and conveyors.

Decarbonization of some of the industrial systems and services can create several benefits for Californians, including improved air quality, reduced greenhouse gas emissions, and significant cost savings. It is also likely that widespread energy management system software adoption can help ensure that equipment is operated efficiently to reduce GHG emissions without sacrificing equipment performance and/or product quality. Widespread energy management could help meet long-term state climate targets with least disruption to manufacturing systems.

Decarbonization of industrial processes generally involves one of the following methods:

- The substitution of natural gas heat with electricity, where economically justified.
- Changing the underlying product design or manufacturing process to increase product outputs using the same or less energy intensity. (An example could be packaging changes using less material)
- Increasing the energy-efficiency of the production process.
- Changing the formulation of materials so that a less intensive proves is required during the manufacturing phase.

Options 1, 2, and 4 have been identified in previous Energy Commission R&D solicitations, but there have been no successful responses. Option 3 has received the majority of proposals, and funded projects are summarized in the next section.

In recent years, EPIC R&D has focused on improving the efficiency of industrial energy-related systems, such as compressed air systems, by demonstrating software programs that benchmark and compare existing operations with industry standards and then identify opportunities for reducing energy use. The Energy Commission is demonstrating sensors and software in facilities such as printing and brewing operations. Other recently funded projects focus on improving compressor and hydraulic system efficiencies, but these projects are just starting. However, preliminary results for the compressed air project show the potential for achieving 15 percent savings. More research is needed to understand energy savings and benefits across more diverse industries and to develop data sets to generate industry baselines. These industry baselines can help facility managers know whether their systems are operating within norms or will need adjustment.

KEY TECHNICAL AND MARKET CHALLENGES

Despite the advancements described above, adoption of previously funded general research and small-scale demonstrations remains an obstacle for several reasons. The industrial sector is very diverse with a wide range of product-specific processes. Before adopting an energy efficient improvement, an industrial facility must be convinced the improvement will maintain or improve product quality.

Major equipment replacements are costly and disruptive to plant operations

Industry is very much attuned to economics and cost. Equipment replacements typically happen in 20- to 30-year cycles, and any down time results in production decreases and revenue losses.

Industries are risk averse

Demonstrations are needed to show that energy savings and benefits are achievable and sustainable while maintaining or improving product quality.

There is uncertainty on the best, cost-effective decarbonization strategies for major industries in California

California is home to thousands of industries. “Compared to other sectors, there has been less attention on low-carbon solutions in the industrial sector.”[45] As a result, Energy Commission staff concludes that there is uncertainty about the best approaches, the cost, and the resulting energy and greenhouse gas reductions for industry.

45 The White House, United States Mid-Century Strategy for Deep Carbonization, November 2016.

Table 14: Previous and Planned EPIC Investments on Industrial Decarbonization

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Software and Sensor Technologies for Compressed Air Facilities	No projects	Unlocking Industrial Energy Efficiency Through Optimized Energy Management Systems (EPC-14-075)
Expanded Demonstration Projects for Promising Technologies	No projects	Development and Testing of an Energy Efficient Ultra-low Charge Ammonia Refrigeration System in a Food Processing Plant (EPC-16-048)-pending Hyper Efficient Pump Motor Unit with Fully Integrated Permanent Magnet Motor and Motor Controls with Combined Liquid Cooling (EPC-16-044)-pending Pilot Testing of Isothermal Compression (EPC-16-046)-pending
Data Center Research	Demonstration of Low-Cost Liquid Cooling Technology for Data Centers (EPC-14-088)	Enabling Energy Efficient Data Centers in Smart Power Distribution Systems (EPC-16-030)-Pending

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

The funding initiatives under this theme aim to develop and deploy strategies and energy efficiency technologies for cost-effective decarbonization of the industrial sector. The first two initiatives focus on deploying sensors and software to optimize refrigeration and compressed air systems. Both systems often operate inefficiently and plant operators do not know whether these inefficiencies are normal. The other two initiatives focus on identifying most cost-effective energy efficiency strategies for decarbonization and large-scale deployment of pre-commercial technologies that can be scalable and replicable in multiple facilities.

Initiative 1.7.1 Optimize Refrigeration Compressor Efficiency and Test and Evaluate Alternative Refrigerants

Description

California has a large population of refrigeration compressors of all sizes operating in virtually every climate zone within the state. Refrigeration compressors generally are designed and head pressures are set to serve peak cooling loads during the hottest summer months. Unfortunately, the same head pressure is typically maintained all year round. Without a provision for automatically adjusting head pressure, the refrigeration compressor consumes the same amount of electrical power year-round.

Automatic control based on outdoor temperature conditions is the most desirable approach but requires the development of effective sensors and a dashboard-based operator system to make it effective. This initiative will develop and deploy improvements in refrigeration compressor control through sensors and software. The improvements could be deployed in a minimum of 50 industries in California. This initiative will prove the viability of the concept and document the savings and benefits. These sensors and software applications will provide information to plant operators of areas of potential waste and has the potential of reducing industrial plant energy by 15 percent.

This initiative will also test and evaluate alternative refrigerants, such as propane, CO2 and others for both small and large refrigeration units in commercial/industrial applications in various climate zones. The focus is refrigerants with low global warming potential and high energy efficiency potential. The research could result in recommendations and best practices for use of alternative refrigerants that are cost-effective and energy efficient for appropriate applications and locations.

Impact if Successful

This initiative could lead to greater adoption and use of optimization sensors and software suites, especially by medium-size industries to improve energy efficiency of refrigeration systems. These industries often are unaware of potential benefits, but need verified data on energy and cost savings prior to taking action.

For alternative refrigerants, the research will help industry/commercial facilities with refrigeration units/cases transition to appropriate low global warming refrigerants that are also energy efficient.

Primary Users and/or Beneficiaries

Industries/commercial facilities with refrigeration units/cases, such as refrigerated warehouses, commercial buildings with walk-in refrigerators and cases (e.g., supermarkets, institutions, food service)

Metrics and/or Performance Indicators

Optimization software will provide a before and after snapshot of efficiency, which will prove the value of the underlying concept.

	The number of industrial/commercial facilities taking action to transition to low GWP refrigerants early, rather than waiting to 2030.
Topic(s) addressed	Optimization software in refrigeration compressors, alternative refrigerants
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development

Initiative 1.7.2 Develop and Deploy Sensors and Software to Optimize Compressed Air and Other Related Systems to Minimize Energy Losses and Maximize Efficiency

Description	Nearly all manufacturing and food processing plants employ compressed air systems to drive various parts of operations. Compressed air is generally the most expensive equipment in a plant. Nearly 80 percent of the electrical power input to a typical compressor is lost as heat due to inefficiency. Most plants have air leakage rates of about 33 percent. Also, many compressed air systems have deviated from the original design and are no longer operating optimally because of system modifications and additions. Moreover, the compressed air systems often run uncontrolled and may continue to run even when the plant itself is not operating. This initiative will develop and deploy sensor and software optimization controls for compressed air systems that can help operators compare current operations to industry standards. The software optimization controls will identify leaks and potential energy and cost savings of fixing the leaks. Plant operators do not have access to metadata level comparisons of compressed air leaks with other similar industries. Large-scale deployment is needed to show the viability and benefits of the concept. This initiative involves a program to deploy sensors and software in up to 500 industries in California. These sensors and software applications will provide information to plant operators of areas of potential waste and have the potential of reducing industrial plant energy by 15 percent.
Impact if Successful	This initiative could lead to greater adoption of optimization sensors and software suites that could improve energy-efficiency of compressed air systems and reduce electricity consumption and cost. Many industrial facilities may be unaware of the energy and cost associated with compressed air

	leaks. A combination of sensors and software tools can help identify leaks, benchmark them to industry standards, and provide verified data on energy and cost savings to inform plant operators.
Primary Users and/or Beneficiaries	Industries that use large amounts of compressed air. Industries include breweries, print shops, mechanics, and agricultural operations among others.
Metrics and/or Performance Indicators	Optimization software will provide a before and after snapshot of efficiency, which will prove the value of the underlying concept.
Topic(s) addressed	Optimization software in compressed air
Value Chain	Demand-side Management
Program Area(s)	Technology Demonstration and Deployment

Initiative 1.7.3 Develop Strategies and Tools for Maximizing Cost Effective Energy Efficiency Strategies for Decarbonization of the Industrial Sector

Description	This initiative will develop strategies that offer the high potential for cost-effective greenhouse gas reduction for major industries in California. The strategies will identify opportunities, best approaches and technologies for implementation in the near term (within 5 years) and mid-term (5-10 years), cost-effectiveness, potential energy savings and greenhouse gas emission reductions, presence in California, and regulatory constraints. The IAW research roadmap, currently being developed, will help narrow the scope of this initiative to target the best opportunities for significant improvement in California's major industrial sectors. The sectors being considered include petroleum refining, food products, electronics, oil and gas extraction, chemical and allied products, glass and cement. The resulting strategies will provide information on the potential carbon reductions technically and economically possible for California.
Impact if Successful	This initiative will provide industries and governmental agencies with a tool to identify approaches and strategies for cost effective decarbonization.
Primary Users and/or Beneficiaries	Industry, government agencies, equipment-users
Metrics and Performance Indicators	Implementation or use of recommendations by those who download publications that report research results

Topic(s) addressed	Technical and Cost Advancements
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development

Initiative 1.7.4 Large Scale Demonstrations of Pre-Commercial Efficiency and Industrial Technologies

Description

This initiative involves the large-scale deployment of previously funded research projects that can reduce industrial energy use by at least 10 percent and be scalable and replicated at multiple facilities. This initiative targets clean energy technologies, such as:

- Motor system improvements advancements including higher efficiency variable frequency drives, wide bandgap semiconductors, harmonizing alternating current and direct current power and improvements in power quality for industrial applications.
- Advanced sensors, controls and platforms for real time management energy, productivity costs and electric grid integration.
- Develop advanced materials that could be used in extreme/harsh conditions, such as high temperatures, pressures, corrosive chemicals and wear that are cheaper, more efficient, and more reliable. Example applications include high temperature or corrosive exhaust gas stacks, CHP exhausts, and heat exchangers.

The targeted technologies must be proven at the pilot stage or have had low market penetration due to high costs. In addition, the technologies must show a path to commercialization within 3-5 years (e.g., including manufacturing partners) and demonstrating that there are potential markets and applications for the technology. This initiative will leverage pilot tests results of promising technologies that have been conducted through the US Department of Energy, National Laboratories, universities, other research organizations and state energy offices. This initiative is designed to have technologies deployed at large scale to demonstrate savings and benefits so that manufacturers can develop a sustainable program to help secure future private funding or participate in pay for performance programs with utilities and others.

Impact if Successful

This initiative will spur market adoption in a broad spectrum of industries using proven, but not yet commercially adopted

	technologies. Potential for new business and energy savings and other benefits to California industries.
Primary Users and/or Beneficiaries	Light and medium industrial facilities without in-house efficiency expertise
Metrics and Performance Indicators	Sales figures from equipment manufacturers
Topic(s) addressed	Technical and Cost Advancements
Value Chain	Demand-side Management
Program Area(s)	Technology Demonstration and Deployment

Table 15: Ratepayer Benefits Summary For Sub-Theme 1.7

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 1.7.1 Optimize Refrigeration Compressor Efficiency and Test and Evaluate Alternative Refrigerants		X			X				
Initiative 1.7.2 Develop and Deploy Sensors and Software to Optimize Compressed Air and Other Related Systems to Minimize Energy Losses and Maximize Efficiency	X	X			X		X		
Initiative 1.7.3 Develop Strategies and Tools For Maximizing Cost Effective Energy Efficiency Strategies For Decarbonization of the Industrial Sector		X		X	X				
Initiative 1.7.3 Large Scale Demonstrations of Pre-Commercial Efficiency and Industrial Technologies	X	X			X			X	

Source: California Energy Commission

CHAPTER 3
Theme 2: Accelerate Widespread Customer Adoption of Distributed Energy Resources

California's energy policies envision a future electricity system significantly more decentralized and decarbonized than the one that developed a century earlier. Driving this transition are *distributed energy resources* (DERs).[46]

Over the past several years, the steep cost decrease in solar PV systems, solid-state lighting, and lithium-ion battery cells used in plug-in electric vehicles and onsite stationary storage systems have helped improve the affordability of DERs. At the same time, more economical and sophisticated information technologies have driven the development of expanded DER capabilities and applications that provide additional value streams to customers.

"DISTRIBUTED ENERGY RESOURCES … ARE DEFINED AS … DISTRIBUTED GENERATION RESOURCES, ENERGY EFFICIENCY, ENERGY STORAGE, ELECTRIC VEHICLES, AND DEMAND RESPONSE TECHNOLOGIES"
CALIFORNIA PUBLIC UTILITIES COMMISSION, DER ACTION PLAN[47]

The market for DER solutions, especially those that integrate multiple customer-side technologies, is still in the early stages of development. Standardization and cost reductions are needed for widespread diffusion of these solutions. Innovative approaches to overcoming barriers to adoption need to be developed evaluated and tested. Barriers include:

- The complexity of assessing the benefits and costs of combining investments in energy efficiency improvements, onsite generation, storage and demand response (DR)-facilitating control systems.
- The risk and uncertainty inherent in estimating future benefits based on evolving utility tariffs and programs.
- The slow development of successful business models for delivering DER services that are fundamental to expanding participation beyond the limits of government and utility programs.

Theme 2 describes funding initiatives that will demonstrate new DER technologies and strategies for deploying DER solutions. Theme 2 DER demonstrations seek to:

Identify optimal technology packages for specific uses and applications that can drive down costs for DERs

Customers hesitate to adopt DER solutions without successful demonstrations that reduce business risk. Demonstrations can help test different technology packages that provide the best financial returns for a specific market segment; and address customer concerns regarding expected performance, operation and maintenance. These demonstrations also provide

46 *DERs* are defined as distribution-connected distributed generation resources, energy efficiency, energy storage, electric vehicles, and demand response technologies.
47 California Public Utilities Commission, *California's Distributed Energy Resources Action Plan: Aligning Vision and Action.* 2016. http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Organization/Commissioners/Michael_J._Picker/2016-09-26%20DER%20Action%20Plan%20FINAL3.pdf

information to DER providers on potentially profitable market segments they should target for entry, helping lower customer acquisition cost barriers.

"WE MUST CONTINUE TO DEVELOP THE MARKET OPPORTUNITIES AND REMOVE MARKET BARRIERS TO UNLEASH THE FULL VALUE THAT DERS CAN PROVIDE"

CALIFORNIA PUBLIC UTILITIES COMMISSION, DER ACTION PLAN[48]

Align planning, permitting, procuring and financing models to facilitate widespread customer adoption of DERs

Many of the current practices, processes, and institutional structures for deploying DER technologies are shaped around incumbent technologies. This can lead to inefficiencies that add time and costs to the acquisition and installation of DER solutions. New strategies, tools and models for financing and deploying DER solutions that expand customer opportunities and motivation for participation need to be developed, tested, and scaled.

48 California Public Utilities Commission, *California's Distributed Energy Resources Action Plan: Aligning Vision and Action.* 2016. http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Organization/Commissioners/Michael_J._Picker/2016-09-26%20DER%20Action%20Plan%20FINAL3.pdf

2.1 Achieve Cost-Effective and Sustainable Retrofits to Highly Energy Efficient Buildings and Communities

The *California Existing Building Energy Efficiency Action Plan* has a goal to increase exponentially the number of ZNE retrofit projects completed in key building types where there is evidence of ZNE technical potential.[49] The general definition of a ZNE building is one that generates as much energy as it uses over a year. Both the *Energy Efficiency Strategic Plan* and the *Existing Building Action Plan* acknowledge that not all buildings – particularly existing buildings – can be cost-effectively built or renovated to meet ZNE metrics and that community-level investments in distributed energy resources in combination with aggressive efforts to achieve all cost-effective energy-efficiency will be required.

THE GOAL IS TO DOUBLE THE EFFICIENCY SAVINGS THAT WE'RE GETTING IN THE STATE…EVEN AS THE ECONOMY AND POPULATION KEEPS GROWING …WE ARE WORKING TOWARD NEGATIVE GROWTH IN NET CONSUMPTION IN OUR BUILDINGS."

COMMISSIONER MCALLISTER
CALIFORNIA ENERGY COMMISSION[50]

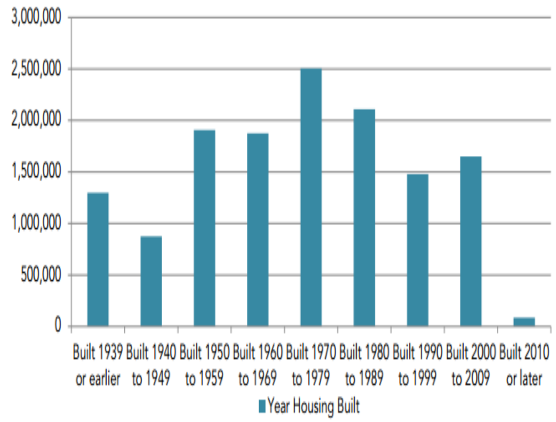
With new construction, it's easier to make big performance improvements over standard practice. Renovating existing buildings is much more challenging, because many sub-optimal design and construction decisions have already been made. Nonetheless, the older, existing building stock is where the most energy efficiency opportunities exist, and there is a need to make renovations more cost-effective. To that end, the *Existing Buildings Energy Efficiency Action Plan* envisions scaling up retrofits with three strategies: Focusing on key building types, developing and/or enhancing retrofit design tool kits, and providing incentives and other financing mechanisms to assist the nascent energy efficiency retrofit market.

Past Energy Commission research has focused on bringing down the cost and increasing efficiency of specific energy-using components. Past research also evaluated renovations of existing homes, multifamily buildings, and small commercial buildings. Although those past efforts developed successful renovation techniques, those techniques are still not widely employed in the renovation market for a number of reasons. These include the need to change traditional building practices, the challenges of engaging and educating the large numbers of independent contractors who make up the retrofit marketplace, and the fact that retrofit costs are still high—largely because the techniques and practices have not reached the scale required to drive costs down.

Recent EPIC research included several research projects focused on maximizing the energy-efficiency of existing commercial and mixed use commercial/residential buildings. These projects plan to demonstrate a sustainable model for high efficiency retrofits.

49 California Energy Commission, Existing Buildings Energy Action Plan, December 2016, http://www.energy.ca.gov/ab758/.
50 http://gettingtozeroforum.org/mcallister-interview/

Figure 9 Age of Housing in California 2010 – 2014 Average



Source: California Department of Housing and Community Development, *California's Housing Future: Challenges and Opportunities*

KEY TECHNICAL AND MARKET CHALLENGES

Dollar savings on energy alone often will not justify the current cost of reaching ZNE or achieving high levels of efficiency in existing buildings. The cost of energy-efficient construction and renovation must drop much further and the value of having a highly-efficient building must be reliably documented, to support rate designs and incentive structures that facilitate the investments required.

"GETTING THE FINANCE, TECHNOLOGY, BUILDINGS AND ENERGY COMMUNITIES OVERLAPPING AND SPEAKING THE SAME LANGUAGE WILL REQUIRE A PRETTY SIGNIFICANT EVOLUTION OF THEIR ABILITY TO GET ACCESS TO DATA THAT CAN INFORM THEIR DISCUSSIONS."

COMMISSIONER MCALLISTER
CALIFORNIA ENERGY COMMISSION[51]

51 http://gettingtozeroforum.org/mcallister-interview/

Scaling Up Zero-Net Energy Retrofits

The *Existing Buildings Energy Efficiency Action Plan* recognizes that scaling up existing building retrofits will depend on:

- Developing a robust industry in which customers understand and trust estimates of future energy cost reductions, and
- Having skilled contractors that can sustain their business by providing efficiency retrofit services.

Achieving these goals requires developing experience with assessing building needs, designing retrofit strategies, implementing those strategies and documenting savings. The Action Plan explicitly identifies first-order opportunities to gain this experience in key building sectors—such as K-12 schools and government buildings—"…where there is evidence of ZNE technical potential, current ZNE guidance, and available financing."[52]

The Resnick Institute at CalTech in partnership with the ETCC and the Moxie Foundation founded the FLOW Rocket Fund to support entrepreneurs to build and test a minimum commercial product. In partnership with the LA Unified School District, the Rocket Fund is developing a field testing program for energy efficiency technologies. The program includes opportunities for high school students to learn about clean energy and entrepreneurship.[53]

52 California Energy Commission, *California Existing Buildings Energy Efficiency Action Plan*. 2015 CEC-400-2015-013-F

53 Rocket Fund. March 29, 2017. Rocket Fund Program Combines Opportunities for Cleantech Companies and Community Education. http://docketpublic.energy.ca.gov/PublicDocuments/17-EPIC-01/TN216745_20170329T165342_Rocket_Fund_Program_Combines_Opportunities_for_Cleantech_Companies_and_Community_Education.pdf

Government and utility entities must also smooth the way for these developments if they are to succeed, and they must also be engaged in both planning and executing solutions.

If approvals and guidance can be obtained at a high enough level, the cost per building unit will decrease. Community leaders must be partners in supporting the renovation projects.

Finance is often a core barrier for energy renovations, especially for moderate income households. Part of the existing stream of energy payments can apply to the capital cost of efficiency upgrades. Owners must also be convinced that the benefits will justify additional investment, which relies on selling non-energy, non-financial benefits. Tenant-owner split incentives are related problems. Experience shows that the value of efficient buildings is more than just the savings of energy and can sometimes attract higher rents.[54]

For low-income multifamily projects, navigating through all the available financing program requirements for energy efficiency, renewable energy and others is complex and time-consuming and conflicting requirements could force building owners to decide on only one path (for example, renewables) and forgo another (for example, efficiency).[55]

Achieving Energy Efficiency Retrofits Combined with On-site Renewable Generation

A recent study by the National Renewable Energy Laboratory estimated that nearly half of residences and businesses in the United States are unable to host their own PV systems.[56] Community-scale installations may be able to open the solar market to these groups, but the details of ownership, cost-sharing and attribution of benefits is challenging – particularly for retrofits. It is also unlikely that a single model would be viable in all circumstances. Research is needed to evaluate possible solutions with building owners and then develop and pilot test the most promising ideas in real-world settings.

Potential for Grid Impacts

Electric utilities often see user generation as compounding their problems; creating safety issues, adverse load shapes and sometimes over-generation. Addressing these issues requires that buildings be highly energy-efficient, and that investments in onsite generation, storage and demand response capabilities be made with consideration of grid impacts and costs. The cost of meeting these criteria building by building can be prohibitive. There is evidence to suggest that strategic community-scale investments in efficiency and DERs driven by careful consideration of grid needs may be a cost-effective way of meeting state energy goals.[57]

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54 https://www.construction.com/about-us/press/world-green-building-trends-smartmarket-report.asp
55 Comment by Samara Larson, Linc Housing, EPIC Symposium, December 2016

56 http://www.nrel.gov/docs/fy15osti/63892.pdf
57 http://www.utilitydive.com/news/how-utility-collaboration-can-cut-community-solar-costs-up-to-40/416304/

Table 16: Previous and Planned EPIC Investments on Retrofits to Highly Energy Efficient Buildings and Communities

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Technology Solutions	S1.2 Improve HVAC and refrigeration systems	S1.1 Advance efficient solutions for lower energy buildings
Model Designs	Zero Energy Residential Optimization – Community Achievement (EPC-15-042) Demonstration of Affordable, Comfortable, Grid Integrated Zero Net Energy Communities (EPC-15-094) Innovative Net Zero: ZNE Demonstration in Existing Low-Income Mixed Use Housing and Commercial Building Application (EPC-15-064) Customer-Centric Approach to Scaling IDSM Retrofits (EPC-15-053) San Diego Libraries Zero Net Energy Demonstration Project (EPC-15-085) Market Zero: Taking an Existing Grocery Store to Scalable Near-ZNE (EPC-15-041) ZNE Demonstration-Integration of Dynamic Daylighting and Passive Cooling and Heating for High Return on Investment (PIR-12-024)-PIER-Electric Project	Measure Results from Affordable Zero Net Energy Homes (EPC-16-001) Pathways to More Cost Effective ZNE Homes (modeling & analysis of all electric versus mixed fuel homes) (EPC-16-002) Achieving Zero Net Energy in Multi-Family Buildings (EPC-15-097) Optimization of Energy Efficiency to Achieve Zero-Net Energy in Multifamily and Commercial Buildings (EPC-16-007) Integrated Whole –Building Zero Net Energy Retrofits for Small Commercial Offices (EPC-16-004)

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

The funding initiatives focus on laying the groundwork for scaling up very efficient retrofits for existing buildings. The goal is to use buildings in conjunction with DERs to provide the flexibility to shape and shift energy usage, shed loads when needed and shimmy to adjust demand on the grid using fast responding resources.[58] At the community scale, highly-efficient buildings, distributed generation, storage and control systems to promote demand response can be combined and optimized to create a value stream that can support initial investments

EPIC funding should be used to leverage other funding from private sources and to serve as a catalyst for larger projects to bring the cost down and demonstrate the value at scale. These

58 Lawrence Berkeley National Laboratory, 2025 California Demand Response Potential Study, March 2017, www.cpuc.ca.gov/General.aspx?id=10622

initiatives aim to discover effective financial elements to achieve a balance of efficiency, renewable energy and energy storage, along with benefits for grid flexibility.

Community Renovation for High Efficiency and Grid Resources

Approaching efficiency renovations, renewable energy, and energy storage at the community level will enable the value of each to be balanced in developing an optimal investment portfolio. Investment and implementation scenarios will be modeled and evaluated in terms of investment costs and avoided energy consumption under different tariff scenarios and customer acceptance. The impact on the grid will be measured as community-level demand at an aggregation point (a circuit or sub-station, for example). It is unclear whether grid needs and policy initiatives (such as identifying a high-need circuit or distribution node and implementing a program) would be more likely to lead to a successful community-scale project than identifying communities that have some kind of existing social organization, such as a neighborhood with a strong community-based organization, a faith community, a municipality or even a neighborhood originally developed as a planned community.

This strategic objective will evaluate the potential for existing communities to develop and pilot innovative strategies for investing in energy efficiency renovations, distributed generation, and storage resources within the community. In the first phase, successful applicants will identify a community, analyze current community consumption patterns and estimate impacts of efficiency, distributed generation, storage, DR control system, EV charging, and other DER investments on grid operations. The second phase will involve the build out of selected projects. The projects should reflect local conditions for investment and local opportunities for community-scale distributed energy resources to provide benefits to the electrical grid.

Initiative 2.1.1 Develop Community Renovation for High Efficiency and Grid Resources

Description	This initiative will initially evaluate the potential for existing communities to develop and pilot test innovative strategies for investing in efficiency renovations, distributed generation and storage resources within the community. It is envisioned that several awards will be made to evaluate the potential in different communities. Projects developed in or by disadvantaged communities will be strongly encouraged to apply and will be given special consideration in allocating awards. In the first phase, successful applicants will identify a community, analyze current community consumption patterns and estimate benefits of a suite of community-scale energy efficiency, distributed generation and storage investments to grid operations. Communities could be composed of participants from multiple customer sectors (for example, residential, commercial, agricultural, industrial, and others) or include multiple locations (e.g., tribal communities). The value

to the community, as defined in the proposal, would be measured in terms of savings relative to investment and operating costs (both for individual and community-level investments). The value to the grid would be measured in terms of the project's benefits for grid operations relative to infrastructure costs. Grid impacts would be measured at the circuit, substation or other aggregation point. In addition, the projects will assess community interest in participation, develop a community engagement and investment strategy and identify a coalition of contractors, community leaders, local government and utility representatives willing to support a pilot test of the strategy. The results from the first phase will be fully developed proposals for the second phase.

In the second phase, participants from the first phase will compete for funding to pilot test the innovative approaches to achieving ZNE or near-ZNE at community scale identified in the first phase. The pilots should reflect local conditions for investment. The pilots should include funding from building owners, local government, and utilities, reserving EPIC funds for collecting data and supporting pilot implementation. An important goal of the second phase is to pilot test business models for community-scale DER that have the potential to become largely self-sustaining and replicable in other, similar communities.

Impact if Successful

As a laboratory for innovation, this initiative will create replicable business models and advance California's goals of dramatically reducing the energy-related environmental impact of existing and new buildings.

Primary Users and/or Beneficiaries

Home and business owners, builders and contractors, local governments, and utilities

Metrics and/or Performance Indicators

- Successful community-scale energy upgrades in existing communities to optimize investments, savings, and access to energy efficiency and DER benefits.
- Explicit optimization of energy efficiency and DER investments from the perspective of participating community members.
- Increased cost-effectiveness of highly efficient buildings and building components.
- Replicable and cost-effective demonstrations of community-scale distributed energy resources.
- Information resources to assist the replication of similar efforts elsewhere.
- Improved value, livability, and environmental sustainability of components, individual buildings, and communities.

Topic(s) addressed	Zero Net Energy communities
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development Technology Demonstration and Deployment

Table 17: Ratepayer Benefits Summary For Sub-Theme 2.1

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 2.1.1 Develop Community Renovation for High Efficiency and Grid Resources	X	X	X	X	X	X	X	X	X

Source: California Energy Commission

2.2 Advance Microgrids to the Tipping Point of Broad Commercial Adoption

California's electric grid must become more resilient and adaptable to climate change impacts such as increased fires, severe storms, and heat waves. Microgrids advance this goal because they are able to island, that is, disconnecting from the grid when necessary to either provide critical support to the end customer or relieve demand on the larger grid. Critical facilities such as hospitals, fire stations, military bases, port authorities, and many communities have found that microgrids provide more assurance that they will have energy when they need it, while enabling generation of clean energy and in some cases, saveings on electricity delivery costs.

Microgrids provide the flexibility that will allow distribution grids in a high DER future to operate efficiently and reliably. Microgrids will help the state of California achieve its carbon reduction goals and will serve as models for integrating a range of distributed energy technologies into the larger grid, including renewable generation, electric vehicles, energy storage, automated demand response and energy use management, combined heat and power systems, and emerging clean energy technologies.

Microgrids also provide the unique ability to evaluate new grid configurations, high concentrations of renewables, assess the impact of a variety of DER systems being installed on the same grid network and the ability to determine the benefit and impact of these different grid configurations. For the research community, microgrids provide an ideal testing capability that is affordable and manageable. The results from microgrid research activities have a direct correlation to the larger grid and help policy makers and grid managers make critical decisions on the future planning activities.

"A MICROGRID IS A GROUP OF INTERCONNECTED LOADS AND DISTRIBUTED ENERGY RESOURCES WITHIN CLEARLY DEFINED ELECTRICAL BOUNDARIES THAT ACTS AS A SINGLE, CONTROLLABLE ENTITY WITH RESPECT TO THE GRID".

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION[59]

Current Microgrid Activities

In the last five years, the activity surrounding microgrids has expanded exponentially.

The U.S. Department of Defense has embraced microgrids as one possible solution to enhance energy resiliency. The Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS) program and the Environmental Security Technology Certification Program have sponsored many microgrid assessments, including Navy and Army projects in California.

The U.S. Department of Energy is funding microgrid research and development to help develop advanced microgrid controllers, integrate energy storage into microgrids, and demonstrate how microgrids can help expand renewables, both utility owned and distributed energy resources. In the 2015 Quadrennial Technology Review, DOE identified the

59 NEMA, Powering Microgrids for the 21st-Century Electrical System, National Electrical Manufacturers Association, NEMA MGRD 1-2016, https://www.nema.org/Standards/Pages/Powering-Microgrids-for-the-21st-Century-Electrical-System.aspx

future role microgrids can play and the need for targeted research and development:

One rapidly increasing role of microgrids is the shift from niche applications (for example, energy security) to the provision of services and benefits from the management of multiple distributed energy resources, such as electric storage, rooftop solar PV, and electric vehicles, in conjunction with building loads. Challenges exist in the development of more complex controllers for microgrids, exploring the benefits of DC microgrid designs, and coordinating nested and networked microgrids with each other and with other distributed energy resources.

In the CPUC White Paper: *Microgrids: A Regulatory Perspective*, the CPUC provided several key challenges, opportunities, and recommendations for regulators to consider.

- The role of the electric utility will change. An option outlined in this paper is to consider the utility as a distribution system operator, akin to an independent system operator on the transmission side.
- There is a need to develop appropriate standards and requirements to ensure that microgrids interconnect and interact with the distribution grid reliably and safely.
- To determine optimal locations for microgrid development, the Commission should map the distribution grid to best identify these locations. This effort can be done in conjunction with the development of distribution grid planning.
- There is a national interest in successful development of microgrids; the Commission should be involved in these efforts to better understand the technical challenges with microgrids, and learn from these efforts to help support appropriate policies.

The CPUC in its Distribution Resource Plan (DRP) Rulemaking (R. 14-08-013) are requiring the IOUs to address these issues in their filings.

Based on the *EPIC 2012 – 2014 Investment Plan*, the Energy Commission awarded seven grants to demonstrate the capabilities and performance of microgrids. In 2016, the Energy Commission, with the assistance of the CPUC and California Independent System Operator (California ISO) began to develop a *Roadmap for the Commercialization of Microgrids in California*. At public workshops for the Roadmap, the seven EPIC awardees were able to present the status of their microgrid development, identify lessons learned in activating their microgrids and highlight some of their successes and challenges in installing and activating their microgrids.[60]

In 2017, under the *EPIC 2015 – 2017 Triennial Investment Plan*, the Energy Commission will solicit projects that demonstrate the capability and value of microgrids and have a clear repeatable market opportunity in a limited segment of the market.

KEY TECHNICAL AND MARKET CHALLENGES

Despite the expanded activities described above, limits on current interconnection, communication, and control technologies; regulatory issues; and market constructs hinder the planning, development, and deployment of microgrids.

60 Workshop was held on September 6, 2016 in Sacramento, CA. Presentations from the workshop are available here: http://www.energy.ca.gov/research/epic/documents/2016-09-06_workshop/presentations/

In the initial two workshops, the Roadmap team identified several barriers to the commercialization of microgrids, most prominently:

- Lack of policies or regulations that enable microgrids.
- Interconnection rules and requirements impose limitations and high costs on microgrids.
- Utility franchise rights inhibit microgrid deployment.
- Existing retail tariffs and lack of direct access to wholesale markets prevent microgrids from monetizing all related benefits.
- Lack of utility understanding of the impacts of end-user microgrids to the utility.
- Adequacy of Institute of Electrical and Electronics Engineers (IEEE) technical standards to address integration and operation of microgrids
- Lack of clearly defined roles and responsibilities between utilities and microgrids
- Lack of standardized methods to establish cost and value of microgrids to various stakeholders

The grants awarded from the *EPIC 2012 – 2014 Investment Plan* are helping to better understand these barriers and develop a consensus on how to assess these challenges on a project by project basis. They are also collecting the data to establish more definitively the value of microgrids in terms of reliability, GHG reductions and cost.

Demonstrations from the *EPIC 2015 – 2017 Investment Plan* will focus specifically on microgrids that have clearly repeatable applications like providing reliability and clean energy services to military bases and California's Port Authorities. Furthermore, this solicitation will demonstrate the value of microgrids to provide improved clean energy services and lower energy costs to disadvantaged communities.

The microgrid roadmap is expected to be finalized by the end of 2017. The recommendations and strategies developed under the Roadmap will be available to the grant awardees of the second and third investment plans.

Table 18: Previous and Planned EPIC Investments on Microgrid Research

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Critical Facilities	City of Fremont Fire Stations Microgrid Project (EPC-14-050) A Renewable Based Direct Current Building Scale Microgrid (EPC-14-053) Laguna Subregional Wastewater Treatment Plant Microgrid (EPC-14-059) Renewable Microgrid for a Medical Center (EPC-14-080)	Future GFO: Demonstrating the Commercial Business Case for Microgrids that supports California's Aggressive Energy and GHG Reduction Policies and Integrates New and Emerging Technologies.
Community Microgrids	Borrego Springs - A Renewable-Based Community Microgrid (EPC-14-060) Demonstrating a Community Microgrid at the Blue Lake Rancheria (EPC-14-054) Las Positas Community College Microgrid (EPC-14-055)	

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

Navigant Research forecasts that global microgrid capacity will be 7.6 GW in 2024 – a fivefold increase from 1.4 GW in 2015, driven largely by the growing number of end-use customers who wish to control their own energy needs in the future.[61] Microgrids give customers the ability to: 1) obtain higher levels of reliability and resiliency; 2) decrease the impact on the climate by installing renewable and other clean energy solutions on the microgrid; 3) evaluate the impact on the grid of installing a high concentration of different types of DER; and 4) participate actively in energy markets as a demand response resource for the servicing utility or by actively participating in energy ancillary service markets like frequency response, non-spinning reserve or other open energy markets.

Barriers to rapid commercialization remain, however. Based on the lessons learned from ongoing microgrid projects and the information gained from public workshops hosted by the Energy Commission and others, this initiative will address these key obstacles in several main areas to develop a business case to commercialize microgrids in California.

61 https://www.navigantresearch.com/newsroom/global-microgrid-capacity-is-expected-to-grow-from-1-4-gw-in-2015-to-7-6-gw-in-2024

Business Case Understanding and Development

Even though there are many microgrids being demonstrated in California and throughout the country, research under the second EPIC investment Plan is specifically developing and demonstrating examples of a consistent and repeatable configuration that can demonstrate the critical elements needed for a microgrid so a clear business case can be demonstrated that will be accepted by the industry, utilities and the regulatory stakeholders. However, this ongoing research is only addressing a limited subset of end use customers (for example, military facilities in California, California Port Authority installations and disadvantaged communities). These demonstrations will begin to define how different levels of reliability and resiliency can be defined, measured, and valued. Also, initial efforts will be initiated to determine how the major benefits of a microgrid can be monetized for these specific opportunities. This initiative will continue to expand that research on a broader and more detailed level that can support end-use customers throughout California. Furthermore, this effort will demonstrate and define the commercial viability of different microgrid configurations by developing a methodology that can clearly define the total costs of the system and the full stream of benefits the system will provide the end customer. This is the key area identified by the stakeholders developing the new *Roadmap for the Commercialization of Microgrids in California*.

Demonstrating how Microgrids can meet the Needs of a Wide Range of End Use Customers

Leveraging the lessons learned from the research and demonstration efforts in the First and Second EPIC Investment Plans, this initiative will continue the efforts to assess, demonstrate and validate the specific features and capabilities of microgrids that meet the energy needs of a wider range of end-use customers, possess the key capabilities these customers require, and have clear and definable benefits that can be monetized. One unique area for microgrids is being able to define the size, structure and complexity of the microgrid that is appropriate for the different end-use customer applications. The initiatives will develop microgrids with clear commercial potential and defined and demonstrated benefit streams. These applications need to identify what capabilities in a microgrid are important to customers; what methodology they can use to select and implement that microgrid and a clear methodology for defining and measuring the benefits and revenue streams that the microgrid will provide. Whether the customer is looking for higher reliability, reduced greenhouse gas emissions, lower energy cost, or new energy capabilities, the result of this research is to provide a suite of options that the customer can select and implement with confidence.

Specific areas expected to be assessed and demonstrated under this initiative are:

- Develop and demonstrate the ability to integrate different DER systems and control systems that provide the end-use customers the capabilities and functions they need and also can be operated in a cost-effective and productive manner.
- Develop and demonstrate different value streams by operating the microgrid with a variety of DER such as energy efficiency, renewable generations, demand response, and energy storage;[62] integrating smart inverters that control volt/VAR output and input;

62 Pam Seidenman, February 10, 2017. Advanced Microgrid Solutions EPIC Triennial Planning Comments. Category: Increase System Flexibility from Low-Carbon Resources. http://docketpublic.energy.ca.gov/PublicDocuments/17-EPIC-01/TN215889_20170210T163451_Pam_Seidenman_Comments_Advanced_Microgrid_Solutions_EPIC_Trienn.pdf.

permitting higher concentration of electric vehicles in a community; and testing other configurations and energy services to achieve the following:

  - Provide energy services to the grid operator such as: 1) ancillary services; 2) capacity deferral for distribution transformer systems; and 3) increasing the capacity of existing distribution systems to absorb higher levels of DER by limiting the negative impact of DER to grid operations.

  - Assess the ability of microgrids to provide grid services to the local utility that will allow higher concentrations of DER on the system without having to upgrade the local distribution system to accept these new DER systems. Also, providing new options to the local utility to respond to increasing load growth from population increases, neighborhoods with higher concentrations of electric vehicles and neighborhoods that are converting to very high concentrations of PV on their homes.

- Demonstrate the benefit of integrating several DER technologies under one microgrid control systems such as: 1) energy efficiency and demand response; 2) energy storage and demand response; 3) renewables and energy storage; 4) renewables and energy efficiency/demand response; 5) integrating the use of high concentrations of electric vehicles onto the microgrid; or 6) optimizing the use of smart inverters, energy storage, renewables and demand response to control the volt/VAR operation of the microgrid while limiting the impact of the microgrid on the local grid.
- Anticipate the need to provide adequate cybersecurity protection for microgrid systems' data.

Initiative 2.2.1 Advance Microgrids to the Tipping Point of Broad Commercial Adoption

Description	This initiative will demonstrate the value a microgrid can bring to end-use customers and provide critical services to the grid operator when needed. By leveraging lessons learned from the research demonstration efforts in the first and second EPIC Investment Plans, this initiative will continue efforts to assess, demonstrate, and validate specific features and capabilities of microgrids that meet the energy needs of a wider range of end-use customers. This initiative will also address key capabilities that customers require and have clear and definable benefits that can be monetized. Furthermore, it will demonstrate how microgrids can help the local utility accept increasing levels of DER without requiring utility system upgrades. This initiative will clearly demonstrate the ability to integrate different DER systems and microgrid control systems that provide end-use customers the energy capabilities and functions they need while operating in a cost effective and productive manner. This effort will focus on developing a clear and definable future commercialization path for microgrids.

Impact if Successful	This initiative will provide a clear pathway to use microgrids to integrate larger concentrations of DER. This initiative will demonstrate where microgrids can be cost effectively and beneficially installed and operated. This will provide a vehicle for California to be the leader in the nation and the world in using microgrids to address climate change issues, and state energy policies. This initiative will also provide end-use customer better energy services and demonstrate the value of microgrid solutions compared to other non-microgrid solutions.
Primary Users and/or Beneficiaries	CPUC, California ISO, Energy Commission, utilities, independent power producers, energy storage developers, vendors, and service providers, U.S. DOE, national labs, CESA, ESA, researchers, and policy makers
Metrics and/or Performance Indicators	Number of commercial standards updated to include microgrids Status of specific recommendations and actions in the Roadmap for the *Commercialization of Microgrids in California*
Topic(s) addressed	Microgrid Commercialization
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development Technology Demonstration and Deployment

Table 19: Ratepayer Benefits Summary For Sub-Theme 2.2

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 2.2.1 Advance Microgrids to the Tipping Point of Broad Commercial Adoption	X	X	X	X	X		X	X	X

Source: California Energy Commission

2.3 Define and Improve the Customer's Business Proposition of Integrated Distributed Storage

DER technologies can offer flexible generation to grid operators and provide GHG benefits comparable to those of larger utility-scale renewable technologies, when coupled with DER, but energy storage technologies can exhibit greater land-use efficiencies, are simpler to permit than conventional generation systems and require less capital equipment resources. However it is also one of the most expensive DER. In some applications, DR can provide similar services to energy storage and in other cases DR is challenged to meet the entire need of the end customer or system. Initial research by DOE indicates that a combination of DR and energy storage may provide a better and more cost effective combined solution than either on their own.

The DER Action Plan (2016) developed by the CPUC calls for implementing a statewide collaboration to foster the development and deployment of emerging DER technologies and DER programs.[63] To reach these goals, California is coordinating with collaborators such as the California ISO, the More Than Smart program, other state agencies like the New York State Energy Research and Development Authority (NYSERDA), and federal agencies including the military and DOE's Advanced Research Projects Agency-Energy.

Distributed energy storage systems are normally included in DER portfolios and in this application can provide very responsive energy services because the energy storage has the most flexibility of any DER system. The challenge is that the cost of energy storage systems remains high compared to the other DER systems and research needs to continue to address new ways to reduce the cost of the distributed energy storage. NYSERDA in RFP 3407 announced in 2017 a desire to develop a comprehensive strategy to reduce soft costs associated with distributed energy storage systems in New York State by 25 percent per kWh by 2019 and 33 percent or more by 2021 compared to a 2015-16 baseline of approximately $220/kWh.[64]The Energy Commission has an active working relationship with NYSERDA and California will benefit from this effort and be able to transfer this knowledge to California energy storage applications. Other areas of cost reductions will continue to need improvements via demonstrations such as understanding which energy storage use case provides the end customer the best value for their investment, how energy storage can best be integrated with other DERs to provide a combined value higher than the sum of the independent systems alone, and how energy storage can be most cost effectively applied to support the residential, commercial and industrial end customers applications.

AB 2514 (Skinner, Chapter 469, Statues of 2010) was first in the nation to direct a utility procurement target for energy storage systems and required Investor-Owned Utilities (IOU) to integrate cost effective energy storage system targets into their renewable energy procurement plans. In implementing AB 2514, the CPUC

63 California Public Utilities Commission California's Distributed Energy Resources Action Plan: Aligning Vision and Action, November 2016.http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Organization/Commissioners/Michael_J._Picker/2016%20DER%20Action%20Plan%20FINAL.pdf

64 Soft costs is defined as: permitting guidance, customer acquisition and best fit customer data analytics, customer and industry education and data collection and analytics

completed a public process and after the process was completed, adopted a statewide target of 1.325 GWs of energy storage for the IOUs to procure by 2020 (installed by 2024). The target includes 200 MW of customer-sided (behind-the-meter) energy storage. In 2016, AB 2868 (Gatto, Chapter 681, Statutes of 2016) added an additional 500 MW of energy storage to this target, including up to 100 MW for behind-the-meter distributed energy storage systems.

KEY TECHNICAL AND MARKET CHALLENGES

Despite the policy activities described above, the expansion of energy storage as a DER service is hindered by to the overall costs of the system, the delays and added costs driven by current interconnection requirements, unclear communication and control requirements to participate in California energy service markets, additional regulatory issues like undefined safety standards and a market that includes many immature or unproven technologies. For example, the energy market has a long history with the operation, capabilities and response times for natural gas peaker plants or customer installed generation systems like natural gas or diesel generators. However, if an energy storage system is selected to replace one of these systems, no battery system or other emerging energy storage technology (except pumped hydroelectric) has a long history (10 years or longer field operating history) to determine what performance can be expected 5, 10 or 15 years in the future.

As stated in the *2016 Integrated Energy Policy Report* (IEPR) *Update*, two additional challenges to unlock locational values of DER (including energy storage) are the difficulty of predicting consumer DER investment decisions and limited transparency into IOUs' distribution planning.[65] Also, comments from More Than Smart for the development of the *EPIC 2018 – 2020 Investment Plan* reiterated the importance of stakeholder participation in planning for high levels of DER.[66] Each EPIC project has a technical advisory committee. Technical advisory committees for DER projects provide an effective mechanism for experts from More Than Smart and other DER planning stakeholders to ensure projects are informed by the latest developments.

The State's Energy Storage Roadmap, *Advancing and Maximizing the Value of Energy Storage technology, A California Roadmap (2014),*[67] notes that for distributed energy storage to be commercially viable, improvement is needed in three arenas:

- Expanding revenue opportunities
- Reducing costs of integrating and connecting to the grid.
- Streamlining and spelling out policies and processes to increase certainty.

As part of the *EPIC 2012 – 2014 Triennial Investment Plan*, the Energy Commission supported research to assess and demonstrate the value, operational safety and commercial potential of different emerging energy storage technologies.

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65 California Energy Commission Staff. 2016. 2016 Integrated Energy Policy Report Update. California Energy Commission. Publication Number: CEC-100-2016-003-CMF. http://docketpublic.energy.ca.gov/PublicDocuments/16-IEPR-01/TN216281_20170228T131538_Final_2016_Integrated_Energy_Policy_Report_Update_Complete_Repo.pdf

66 Tony Brunello, President, More Than Smart. February 10, 2017. More Than Smart Comments on EPIC Plan for 2018-2020. http://docketpublic.energy.ca.gov/PublicDocuments/17-EPIC-01/TN215910_20170210T165549_Tony_Brunello_Comments_More_Than_Smart_Comments_on_EPIC_Plan_fo.pdf

67 www.energy.ca.gov/research/energystorage/tour/roadmap/

Seven grants were awarded from this plan. Awardees experienced the same challenges identified in the Energy Storage Roadmap: technical hurdles, long wait times to obtain permits and interconnection agreements, and difficulties in determining the most beneficial uses of the technology. To address these issues, new processes and methods need to be developed, tested, and proven to improve the cost-benefit value of distributed energy storage systems.

In *the EPIC 2015 – 2017 Investment Plan*, distributed energy storage is addressed as a component of a larger system instead of as a stand-alone technology solution. Two main areas of research address energy storage. First, the Energy Commission is soliciting new microgrid projects that can include energy storage. These will address strategies to improve the value of services energy storage provides the microgrid. These demonstrations will help define how energy storage can more effectively participate as part of a larger grid system. Second, projects were awarded that will integrate energy storage with solar technology so the benefit and value of the combination can be demonstrated and measured. This effort will focus on projects that will advance the deployment and grid integration of distributed resources thought the use of energy storage, smart inverters, and advanced forecasting and modelling techniques. These projects will move these technologies closer to commercial acceptance. However, these applications will only provide part of the advancements needed to maximize the complete value of distributed energy storage.

Table 20: Previous and Planned EPIC Investments on Integrated Distributed Storage

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Testing Energy Storage Value and Potential	Energy Storage Valuation and Optimization Tool (EPC-14-019) Utility Demonstration of Znyth Battery Technology to Characterize Performance and Grid Benefits (EPC-14-023) High Temperature Hybrid Compressed Air Energy Storage (HTH-CAES) (EPC-14-027) Pilot Testing of Eos' Znyth Battery Technology in Distributed Energy Storage Systems (EPC-15-018) A Transformative Flywheel R&D Project (EPC-15-016)	No projects
Testing the Value of Energy Storage as a Part of a System Solution	Demonstrating a Community Microgrid at the Blue Lake Rancheria (EPC-14-054) City of Fremont Fire Stations Microgrid Project (EPC-14-050) Laguna Subregional Wastewater Treatment Plant Microgrid (EPC-14-059) Renewable Microgrid for a Medical Center (EPC-14-080) A Renewable Based Direct Current Building Scale Microgrid (EPC-14-053) Las Positas Community College Microgrid (EPC-14-055) Borrego Springs - A Renewable-Based Community Microgrid (EPC-14-060) Enabling DNP3 Support of Energy Storage-Use Cases (EPC-15-089; Prime: Electric Program Research Institute; Subcontractors: MESA Standards Alliance, SunSpec Alliance, and Xanthus Consulting International	Future GFO: Demonstrating the Commercial Business Case for Microgrids that supports California’s Aggressive Energy and GHG Reduction Policies and Integrates New and Emerging Technologies.
Building-Scale PV and Storage	No projects	Solar+: Taking the Next Steps to Enable Solar as a Distribution Asset (GFO-16-309)
Community-Scale PV and Storage	Demonstration of Community Scale Low Cost Highly Efficient PV and Energy Management System (EPC-15-085) College of San Mateo Internet of Energy (EPC-14-083) Demonstration of Community Scale Generation System at the Chemehuevi Community Center (EPC-15-003)	Solar+: Taking the Next Steps to Enable Solar as a Distribution Asset (GFO-16-309)

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

This initiative will address the research actions needed to move distributed energy storage closer to commercial acceptance as a DER service in California by demonstrating new solutions to challenges distributed energy storage faces today. The initiative will demonstrate and evaluate: financial structures to clarify the value of energy storage, develop new methods and techniques to streamline areas of historical challenges like interconnection procedures, lower the cost and time to needed obtain utility and local government approvals of proposed distributed energy storage installations, new technologies and products that reduce the metering equipment costs to participate in energy services with the utility and California ISO, and apply the lessons learned from these efforts to develop new recommended industry technical standards, protocols, guidebooks and other tools that will ease the complexity and lower the overall costs of installing and operating distributed energy storage in the future.

Initiative 2.3.1 Development of Customer's Business Proposition to Accelerate Integrated Distributed Storage Market

Description

Based on information obtained from prior EPIC research projects, the State's Energy Storage Roadmap and the public DER activities hosted by the CPUC, research will need to address some or all of the following key actions:

- Research, develop and demonstrate new streamlined grid interconnection capabilities that substantially lower the costs and time required to meet local utility and grid management needs.
- Evaluate new technology solutions that make the process simpler and require less equipment, and lower field connection and installation costs.
- Research, assess and demonstrate new energy storage telemetry technologies that will meet utility and California ISO requirements and substantially lower cost than currently certified telemetry equipment.
- Based on lessons learned from previous research and demonstration projects, develop recommended standards, protocols, procedures, guidebooks and other tools or services that will help accelerate the end customer acceptance and the commercial viability of these distributed energy storage systems.
- Research methods of lowering the cybersecurity risk to distributed energy storage systems and data while avoiding the collection or release of sensitive information.

	• Develop, evaluate and demonstrate financial structures to monetize the values provided by energy storage technologies for grid reliability, GHG reductions, grid emergency backup services and societal services.
Impact if Successful	This effort will provide the solutions to challenges impacting the cost and effectiveness of installing and using distributed energy storage in California. These solutions will provide the energy storage industry demonstrated and successful options to current cost and benefit barriers that are prohibiting the distributed energy storage industry from reaching its true potential. These efforts will assist the CPUC and California's IOUs as they implement AB 2514 and AB 2868 by ensuring that the most cost effective decisions are made on applying energy storage as DER on the grid and that the values provided by energy storage DER services are validated, more easily monetized and more effectively implemented.
Primary Users and/or Beneficiaries	CPUC, California ISO, Energy Commission, utilities, independent power producers, energy storage developers, energy storage vendors, and DER service providers, DOE, national labs, CESA, ESA, researchers, and policy makers.
Metrics and/or Performance Indicators	• Clearly defined revenue opportunities for distributed energy storage in California and a better understanding of how these opportunities illustrate the commercial viability of energy storage as a DER. • Overall industry acceptance of the valuations and benefits defined in the documents and tools provided by this initiative
Topic(s) addressed	Commercialization of energy storage as a DER service
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development Technology Demonstration and Deployment Market Facilitation

Table 21: Ratepayer Benefits Summary For Sub-Theme 2.3

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 2.3.1 Development of Customer's Business Proposition to Accelerate Integrated Distributed Storage Market	X	X	X	X	X		X	X	X

Source: California Energy Commission

2.4 Incentivize DER Adoption through Innovative Strategies at the Local Levels

The scale and scope of California's energy and climate goals will require action and support at all levels and from all parts of the state. California's local governments and communities will play a crucial role in achieving these goals, developing new solutions and innovations at the local levels that can help catapult clean energy investment at unprecedented levels.

In line with the state's clean energy goals, several cities across the state have adopted goals for achieving 100 percent renewable energy, ZNE buildings, or carbon neutrality; and several more are exploring ways to adopt similar goals. California's Office of Planning and Research (OPR) identified that approximately one third of California cities have a General Plan that addresses renewable energy, even more have General Plans that address greenhouse gas emission reductions, and over 20 percent of California cities are addressing climate adaptation in their plans as of late 2016.[68]

As communities across California take action to improve the sustainability and resiliency of their jurisdictions, communities are looking to integrated DER solutions.

In 2016, the Energy Commission launched the EPIC Challenge, a two-phased competition that challenges multi-disciplinary teams to conceptualize and build an Advanced Energy Community (AEC) that can serve as a model for other communities looking to integrate DER and other clean energy technologies into their jurisdictions. Phase I required project teams to develop innovative permitting, planning and financing mechanisms to accelerate the deployment of AECs, as well as develop a community master plan to bring their vision of an AEC to a shovel-ready status. Phase II of the EPIC Challenge, which is only open to Phase I awardees, will fund the build-out of the best plans and designs developed during Phase I.

The 13 projects awarded under Phase I covers both northern and southern California, and seven of the projects are located in disadvantaged communities.

KEY TECHNICAL AND MARKET CHALLENGES

One of the largest hurdles to expanding adoption of DER is that most local governments and communities lack the means, financial and otherwise, to pursue and pilot creative new approaches for reimagining energy in their communities.

For those communities exploring DER as a possible pathway to a more sustainable and resilient community, customers and policymakers are hesitant to adopt new DER solutions into their decision-making because of the market's early stage.

Standardize Planning and Permitting Requirements for DER Technologies across California

California has over 500 Authorities Having Jurisdiction (AHJs) each with their own planning and permitting processes, which can add significant time and cost to the deployment of DER. The solar PV sector has made great headway in reducing these costs, standardizing and streamlining the patchwork of requirements throughout the state.[69] Reduction of these soft-costs has

68 Governor's Office of Planning and Research, *2016 Annual Planning Survey Results*. 2016. https://www.opr.ca.gov/docs/2016_APS_final.pdf

69 Governor's Office of Planning and Research, *California Solar Permitting Guidebook*. 2017.

contributed to the steep decline of overall PV installation costs over the past few years.[70] This same aggressive reduction of soft-costs now needs to be applied to other DER technologies, such as storage, as well as community scale developments that integrate multiple DER technologies. These new technology deployments face a similar planning and permitting landscape that PV encountered 10 years ago, with local cities and counties unfamiliar with how to properly deploy these technologies in their jurisdictions. Continued research is needed to help AHJs evaluate DER projects, thereby increasing their deployment throughout the state. As hardware and module costs of DERs come down due to technology advancements, the share of system costs associated with soft-costs will become an increasing barrier to wider adoption and deployment.

Reduce Barriers for Medium to Large Institutions to Procure DER Technologies

DER vendors looking to deploy their technologies see great opportunity in medium to large institutional customers, such as school districts, ports, and military bases. However, these vendors are often unsuccessful when bidding for contracts with these customers due to a lack of resources needed to comply with regulatory and administrative hurdles. Conversely, these customers often wish to install more DER technology, but lack the technical expertise to evaluate and select the appropriate mix of technologies to fit their needs. The result of this disconnect is that DER vendors miss opportunities to deploy their technologies on larger scales, and customers miss out on new, emerging clean energy technologies that could provide valuable services.

Innovative Financing Mechanisms for Community-Scale Deployment of DERs

Despite decreases in both hard and soft costs in DER technologies, DER systems remain relatively expensive when compared to incumbent technologies. Innovations in financing mechanisms have done a great deal in supporting the recent proliferation of solar PV. Financing tools such as property-assessed clean energy (PACE) programs and power-purchase agreements (PPAs) have helped lower the relatively high upfront costs of PV and contributed to the sharp increases in solar installations throughout the state. Community-scale DER systems require similar innovations in financing. These systems may be installed on multiple locations serving multiple users across a neighborhood with no clear single owner or operator. Innovations in financing community-scale developments can help open untapped sectors for clean energy deployment.

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https://energycenter.org/sites/default/files/docs/nav/policy/research-and-reports/Solar_Permitting_Guidebook_2017.pdf

70 Barbose, Galen and Naim Darghouth, *Tracking the Sun IX*. 2016. https://emp.lbl.gov/sites/default/files/tracking_the_sun_ix_report.pdf

Table 22: Previous and Planned EPIC Investments on DER Adoption at Local Levels

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Advanced Energy Communities	ZipPower San Leandro (EPC-15-052) The Charge Bliss Advanced Renewable Energy Community for a Disadvantaged Southern California Community (EPC-15-055) Peninsula Advanced Energy Community (PAEC) (EPC-15-056) The Oakland EcoBlock - A Zero Net Energy, Low Water Use Retrofit Neighborhood Demonstration Project (EPC-15-058) Using Data-Driven Approaches to Design Advanced Energy Communities for Existing Buildings (EPC-15-061) Berkeley Energy Assurance Transformation (BEAT) Project (EPC-15-065) Developing an Advanced Energy Master Plan for the Encanto Neighborhood in San Diego (EPC-15-066) Integrated Community Resource Marketplace (EPC-15-067) Lancaster Advanced Energy Community (AEC) Project (EPC-15-069) Zero Net Energy Farms (EPC-15-071) Richmond Advanced Energy Community Project (EPC-15-076) Huntington Beach Advanced Energy Community Blueprint (EPC-15-077) Santa Monica Advanced Energy District (EPC-16-008)	Phase II of the EPIC Challenge

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

The Energy Commission will advance initiatives building off of ongoing work in the planning and permitting of advanced energy communities integrating DER. New initiatives will seek to establish tools and resources and best practices for jurisdictions looking to increase community sustainability and resiliency either at new construction, in-fill, or retrofit projects. These initiatives will promote greater adoption of DER across the state, sharing the energy and non-energy benefits of DER to more California communities.

Initiative 2.4.1 EPIC Challenge

Description	In 2016, the Energy Commission launched the EPIC Challenge, a two-phased competition that challenges multi-disciplinary teams to conceptualize and build an Advanced Energy Community (AEC) that can serve as a model for other communities. Thirteen projects were awarded under Phase I. This initiative will fund Phase II of the EPIC Challenge, which will fund the build-out of the most promising designs and plans that result from Phase I. This initiative will also fund a second EPIC Challenge to further advance the comprehensive clean energy plans, regulations, and codes of cities and communities across California. This initiative will fund competition(s) that will challenge project teams to develop innovative and replicable approaches for accelerating the deployment of Advanced Energy Communities and explore the potential for Energy Districts, aggregated energy metering (especially in the agricultural sector), and curbing soft costs for customer-side energy storage deployment. This initiative will include ZNE challenged sectors and have a focus on disadvantaged communities
Impact if Successful	Could demonstrate the feasibility of innovative planning, permitting and financing approaches at the local and regional levels, and incentivize the development of Advanced Energy Communities and increased adoption of DER. By pre-establishing energy storage and other DER siting requirements and regulatory pathways, this initiative could help ensure that California cities and communities are equipped to adopt innovative DER technologies. Could facilitate the identification, collection, and distribution of California builders, small businesses, and vendors who can provide, install, and/or maintain clean energy technologies, including DER. Could help establish best practices for engaging community organizations in the planning, design, and deployment of clean energy communities and advance best practices for collaboration between planners of Advanced

	Energy Communities and the residents and leaders of low-income and disadvantaged communities
Primary Users and/or Beneficiaries	Ratepayers who will be purchasing clean energy technologies, local governments, environmental organizations, agricultural organizations, developers of clean energy technologies, building developers, community organizations
Metrics and Performance Indicators	Increase in community-scale DER adoption in cities and communities across California
Topic(s) addressed	Distributed Energy Resources Community-Scale Developments Planning and Permitting
Value Chain	Market Design
Program Area(s)	Technology Deployment and Demonstration Market Facilitation

Table 23: Ratepayer Benefits Summary For Sub-Theme 2.4

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 2.4.1 EPIC Challenge	X	X	X	X	X	X	X	X	x

Source: California Energy Commission

CHAPTER 4
Theme 3: Increase Grid System Flexibility and Stability from Low-Carbon Resources

SB350 established a new 50 percent target for California's Renewables Portfolio Standard. In 2015, the California Global Warming Solution Act was updated to require GHG reductions of 40 percent by 2030. For California to meet these goals and continue to drive down the cost of electricity generation, new innovations are needed that will increase the use of low-carbon resources for grid flexibility and stability.

> "THERE IS A GROWING NEED FOR FLEXIBLE RESOURCES TO COMPENSATE FOR HOURLY CHANGES IN RENEWABLE GENERATION AND ENERGY DEMAND"
> CALIFORNIA ENERGY COMMISSION, 2016 IEPR UPDATE[71]

Solar PV has become the preferred technology option for renewables in California, accounting for 97 percent of new utility-scale renewable generation added in 2016.[72] This trend is expected to continue as solar PV prices continue to approach and even surpass cost parity with conventional generation. However, "The characteristics of PV-generated electricity – including variability, uncertainty, and non-synchronous generation – present challenges to large-scale, cost-effective grid integration."[73]

In 2016, NREL examined the California grid with high-penetrations of solar PV. The study found that with limited system flexibility, curtailment costs needed to maintain reliability would negate gains made in solar PV prices by the time solar PV reaches 20 percent of annual electricity demand.

> "ENHANCED FLEXIBILITY COULD KEEP PV COMPETITIVE AT 25 PERCENT PENETRATION"
> NATIONAL RENEWABLE ENERGY LABORATORY, ON THE PATH TO SUNSHOT[74]

Several options exist for increasing system flexibility and stability from low-carbon resources including: demand response; energy storage; smart inverters, which change the way the grid is scheduled and dispatched; and balancing supply and demand over larger geographic areas.

The funding initiatives described in this theme will further enable these strategies

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71 California Energy Commission Staff. 2016. 2016 Integrated Energy Policy Report Update. California Energy Commission. Publication Number: CEC-100-2016-003-CMF http://docketpublic.energy.ca.gov/PublicDocuments/16-IEPR-01/TN216281_20170228T131538_Final_2016_Integrated_Energy_Policy_Report_Update_Complete_Repo.pdf

72 Calculations based on Table 2, California Energy Commission – Tracking Progress: Renewable Energy-Overview, http://www.energy.ca.gov/renewables/tracking_progress/documents/renewable.pdf

73 Palmintier, Bryan, Robert Broderick, Barry Mather, Michael Coddington, Kyri Baker, Fei Ding, Matthew Reno, Matthew Lave, and Ashwini Bharatkumar. 2016. *On the Path to SunShot: Emerging Issues and Challenges in Integrating Solar with the Distribution System*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5D00-65331. http://www.nrel.gov/docs/fy16osti/65331.pdf

74 https://energy.gov/sites/prod/files/2016/05/f31/OTPSS%20-%20Executive%20Summary-508.pdf

by advancing system-level science and technology innovations that:

Accelerate the development and adoption of communication-enabled devices and controls.

Many low-carbon flexibility strategies will rely on increasingly sophisticated and ubiquitous communication and control technologies. For example, "[system] operators might need the ability to control the output of [distributed] resources to maintain a reliable grid."[75] Further efforts are needed to increase the functionality and interoperability of communication and control technologies and facilitate their adoption into consumer-level and grid-level devices.

Improve the performance and economics of power electronics used in grid-connected customer devices.

While significant attention has been made to communication and control systems, opportunities exist to improve power electronics used to convert, control, and monitor power flows in grid-connected consumer devices such as electric vehicle chargers, battery storage, and smart inverters. Material advancements can potential reduce the size and cost, as well as drive technical improvements to the operating range, power quality and conversion losses of these devices.

Enhance data analytics and tools used to optimize system planning and operation of low-carbon energy resources.

"Real-time data at fine granularity and a suite of analytical tools and models will constitute the backbone of a modern, cleaner electricity system that integrates variable renewables and energy-saving technology."[76]

"DERS PARTICIPATE ROBUSTLY AS GRID RESOURCES THROUGH PROGRESSIVELY GREATER VISIBILITY, DISPATCHABILITY, AND PROFITABILITY IN WHOLESALE GRID OPERATIONS"
California Public Utilities Commission, DER Action Plan[77]

75 Ibid

76 Department of Energy, *Quadrennial Energy Review Transforming the Nation's Electricity System: The Second Installment of the QER*. 2017 https://www.energy.gov/sites/prod/files/2017/02/f34/Chapter%20III--Building%20a%20Clean%20Electricity%20Future.pdf

77 California Public Utilities Commission, *California's Distributed Energy Resources Action Plan*. September 2016. http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Organization/Commissioners/Michael_J._Picker/2016-09-26%20DER%20Action%20Plan%20FINAL3.pdf

3.1 Accelerate Broad Adoption of Automated Demand Response Capabilities that Provide the Grid Flexible Response Services

As the state moves toward more distributed generation and intermittent renewable energy generation, distributed demand-side resources will play a growing role in distribution and transmission grid management. Demand response (DR) can help smooth a renewables-heavy grid by shifting load away from the high ramp periods, raising the belly of the duck curve to limit renewable curtailment, and balancing variable generation with the help of smart communicating technologies both behind the meter and on the grid. DR can also provide load reductions where grid capacity is locally constrained and, when bundled with distributed energy resources, provide customers with the ability to modify their load shapes to address system needs while also meeting their own consumption needs and cost constraints.

Demand response has been first in the loading order along with energy-efficiency since 2003, with fast-response DR preferred to new generation capacity. With digital communications and consumer device automation capabilities growing rapidly, California's vision was to lay the groundwork for communicating grid needs to customer-controlled energy management systems and end-use devices to facilitate automated response. Energy Commission research funding established the OpenADR (Open Automated Demand Response) communication protocol and obtained state-level and national-level approval of this protocol as an industry standard. In the last decade, the IOUs distributed smart meters to most customers, and Title 24 standards require businesses to be auto-DR ready. By 2015, IOU customers were providing 2,147 MW of DR capacity, mostly as interruptible load, enough to cover nearly 5 percent of California ISO peak system demand.

In 2013, the Energy Commission, the California ISO and the CPUC collaborated with stakeholders to develop the *Demand Response and Energy Efficiency Roadmap*. The roadmap articulated a vision for DR that went beyond peak load reduction and emergency reliability to enabling and expanding demand-side customer participation in providing flexible, locational resources to reduce the cost—in both infrastructure investment and carbon—of integrating increasing levels of renewable resources. The roadmap also laid out a framework organize demand resources into "supply" and "load reshaping" categories and laid out "pathways" for action by the Energy Commission, CPUC, and the IOUs. The Energy Commission immediately followed through in the 2013 IEPR process by setting detailed policy direction and laying out plans for including DR in the electricity supply and demand forecasts and identifying research needs. The California ISO continued work to develop mechanisms for including DR resources in wholesale energy markets. The CPUC opened a new DR Rulemaking (R.13-09-011) which codified the pathways into a "bifurcation" between "supply" and "load modifying" resources (D.14-03-026) and began developing functional details for the utilities to follow in procuring and incentivizing DR. The CPUC also commissioned a DR Potential Study to assess and evaluate the technical capability of customers to shed or take energy, assess the economics of participation, and discuss scenarios for market adoption. This effort is the most comprehensive study for the uses of DR for California's grid in more than a decade.

The DR Potential Study found that additional peak demand should be met with planned generation through 2025, and DR should focus on dynamic load balancing and offsetting local capacity constraints. Substantial research and technology development over the past decade have pointed toward a vast untapped potential for balancing electricity supply and demand in near-real time through better management of customer loads and distributed energy assets. The DR Potential Study expects that within 10 years, "enabling technologies will be able to communicate and interface together to provide end use control and response to signals from an aggregator, consumer, or utility." Standardized communications will improve, allowing faster response times, and "telemetry of distributed DR resources can be simplified to allow for great access to the wholesale market in California."

The *EPIC 2012 – 2014 Investment Plan* addressed participation barrier issues identified in the DR Potential Study by funding innovative approaches to engage customers and provide DR resources. The Energy Commission's Advancing Solutions that Allow Customers to Manage their Energy Demand solicitation awarded more than $30 million for 10 projects across the residential and commercial sectors. The projects tested different methods of engaging customers and providing DR resources to the grid with the goal of identifying effective customer engagement strategies and assessing customer response to different incentive structures and participation rules. One project was designed with the goal of providing a benchmark incentive structure to compare impacts between the different project engagement strategies and customer groups participating in the other projects. This awardee is developing a transactive signal that incorporates information about system conditions and system needs that can be used as a basis for managing load.

Another solicitation – Advancing Cutting-Edge Technologies and Strategies to Reduce Energy Use and Costs in the Industrial, Agriculture and Water Sectors – awarded about $13 million in projects designed to develop and assess DR strategies for the agricultural and industrial water sectors. The six projects will be exploring DR strategies for irrigation control, water transport, water treatment and industrial refrigeration.

KEY TECHNICAL AND MARKET CHALLENGES

The DR Potential Study points out that current market designs limit the scale of DR potential by limiting opportunities for participation to customers and loads that can meet narrow participation requirements. These limitations reflect the primary obligations of the CAISO and CPUC to provide reliable electricity service at a reasonable cost. Uncertainty about the actual performance of DR strategies and the difficulties in measuring impacts diminishes the value to the grid that is attributed to DR resources, which reduces the incentive to participate. The need to bifurcate DR into supply and load-modifying categories reflects this dilemma by limiting the attribution of capacity value only to loads that can meet strict performance and telemetry requirements. The rollout of the Demand Response Auction Mechanism (DRAM) made significant inroads into addressing this problem for aggregated loads. However, the DR Potential Study notes that "Stakeholders perceive a risk for investing in fast DR technologies that have poorly defined markets for DR participation and compensation in California ISO," and that there is “great uncertainty on the value for providing DR in real time markets.”

The DR Potential Study also points out that current market designs limit the scale of DR potential by limiting DR incentive programs and contracts to a narrow set of technologies, which California ISO and the CPUC believe will provide reliable electricity service at a reasonable cost, and avoid unproven technologies. Even for incented DR strategies, potential customers may balk at uncertainty about how the strategy will perform for them or what compensation they will receive given the difficulties inherent in measuring impacts.

While current EPIC investments in DR research are addressing some of these challenges, the results will feed back into program and market design – resulting in changes in the participation rules and incentive structures. As the market evolves and participation grows – especially as the CPUC follows through on implementing Time of Use (TOU) rates for small customers – additional work will be needed to assess evolving market impacts and potential response strategies. Additional research and development will be needed in the areas of market design, customer response strategies and automation technology.

Table 24: Previous and Planned EPIC Investments on Demand Response

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Residential Demand Response	Assessing the Ability of Smart Inverters and Smart Consumer Devices to Enable More Residential Solar (EPC-14-079)	No current or planned investments
Commercial Demand Response	Increasing Workforce Development Opportunities in Disadvantaged Communities through Automated Demand Response Communication Equipment Training (EPC-15-010)	No current or planned investments
V2G with Aggregated Resources	Next-Generation Grid Communication for Residential PEVs (EPC-14-078) Distribution System Aware Vehicle to Grid Services for Improved Grid Stability and Reliability (EPC-14-086) Open Source Platform For Plug-in Electric Vehicle Smart Charging in California (EPC-15-013)	Advanced Vehicle-Grid Integration Research and Demonstration (GFO-16-303)
Transactive Energy	Transactive Incentive Signals to Manage Electricity (EPC-15-045) Powernet - A Cloud Based Method for Managing Distribution Resources (EPC-15-047)	No current or planned investments
Load Management Systems that Facilitate Participation as Supply-Side Resources	Total Charge Management: Advanced Charge Management for Renewable Integration (EPC-15-084) Meeting Customer and Supply-side Market Needs with Electrical and Thermal Storage, Solar, Energy Efficiency and Integrated Load Management Systems (EPC-15-074) Empowering Prosumers to Access Wholesale Energy Products (EPC-15-083	No current or planned investments
Load Management Systems that Facilitate Participation as Demand-Side Resources	Customer-centric Demand Management using Load Aggregation and Data Analytics (EPC-15-075) Residential Intelligent Energy Management Solution: Advanced Intelligence to Enable Integration of Distributed Energy Resources (EPC-15-048) Customer-controlled, Price-mediated, Automated Demand Response for Commercial Buildings (EPC-15-077) Complete and Low Cost Retail Automated Transactive Energy System (EPC-15-054) Identifying Effective Demand Response Program Designs for Small Customer Classes (EPC-15-073)	No current or planned investments

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

The main purpose of this research is to enable high renewable resource penetration and meet carbon emissions goals by facilitating the more effective use of DR by all sectors of California IOU customers. The specific categories of research include the impact of different types of rate and tariff designs on customer participation and response and wholesale DER market, integration and interconnection.

Develop and pilot test market designs

Innovative incentive programs, rate designs and market structures will require evaluation and assessment for their effectiveness in addressing specific system needs by identifying specific subsets of end-use loads that have the technical ability to respond at the least opportunity cost to the customer. A number of approaches are currently in the initial stages of exploration under the EPIC *2012 - 2014 Investment Plan*. The results of those projects will identify promising approaches as well as dead-ends. They will also show opportunities for additional innovation and reveal gaps in existing opportunities for different end uses and customers. Additional work will be needed to refine participation and incentive requirements, document impacts, and assess customer acceptance of the approaches currently being developed. In addition, innovative approaches will still be needed to realize technical and economic opportunities that this initial group does not address. Changes in market and rate designs have complicated and often unforeseen impacts on grid operations, costs and customers. Grid operators responsible for system reliability require a high level of confidence in the predictability of load response while utilities and regulators are rightly concerned with customer impacts and costs. Thus DR market, rate and program designs require thorough and careful pilot testing and demonstration before they can be ready for adoption.

Assess the performance of load control systems and technologies

The ability to forecast impacts and design markets and incentive structures will require reliable estimates of performance under different conditions and at different times. The work should focus on the performance assessment on technical system needs (specific ancillary services; balancing renewable variability; meeting local needs). The goal is to build sufficient data on performance to reduce uncertainty and provide sufficient confidence in DR reliability that is transparent (to the system operator) so that telemetry on each load is unnecessary. The ultimate purpose of multiple assessments would be to facilitate a portfolio approach in which different types of end uses and combinations of DERs would participate when available and when the opportunity cost of responding falls below the value to the system. This initiative will also research methods of lowering the cybersecurity risk to demand response and data, while avoiding the collection or release of sensitive data.

Initiative 3.1.1 Pilot Test for the Next-Generation Demand Response Landscape

Description	Develop and pilot test market designs (wholesale and retail rates and tariffs), incentive structures and programs that address specific system needs by identifying specific subsets of end-use loads (by technology and/or customer type) that have (or could develop) the technical ability to respond at the least opportunity cost to the customer and identifying what participation and incentive requirements would encourage participation. These pilot tests would necessarily include both load management alone and different combinations of DERs, including onsite generation and storage to provide a better understanding of effective investment strategies for different types of customers with different consumption needs. The retail elements of these market designs, incentive structures and programs could be implemented by either utilities or third party aggregators.
Impact if Successful	Demand response would be more widely adopted, because it would entail more desirable (less costly) customer actions, would be better incented, and address more technologies.
Primary Users and/or Beneficiaries	Electricity customers in all sectors could participate. Nonparticipant ratepayers benefit by having a smoother functioning, more reliable, less costly electricity grid.
Metrics and/or Performance Indicators	Customer participation levels, load response, and level of incentive needed to ensure participation Participant satisfaction and retention rates Load shaping (reducing the steep afternoon ramp) and other beneficial changes to the duck curve Reduced need for generation or T&D capacity in congested locations Value, amounts, and types, of ancillary services provided to the grid Ability of structures to reward battery + DR synergies
Topic(s) addressed	Demand response market design
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development

Initiative 3.1.2 Assess Performance of Load Control Systems

Description	Assess the performance of load control systems and technologies and develop reliable estimates of performance under different conditions and at different times. Focus the performance assessment on technical system needs (specific ancillary services; balancing renewable variability; meeting local needs). The goal is to begin building sufficient data on performance to reduce uncertainty and provide sufficient confidence in DR reliability that is transparent (to the system operator) so that telemetry on each load is unnecessary. The ultimate purpose of multiple assessments would be to facilitate a portfolio approach in which different loads would participate when available and when the opportunity cost of responding falls below the value to the system.
Impact if Successful	Demand response technologies and strategies would be more widely adopted, because they would entail more desirable (less costly) customer actions, would be better incented, and address more technologies.
Primary Users and/or Beneficiaries	Industrial and commercial customers with flexible loads and/or some combination of PVs, storage and load management technology. DR Providers, LSEs and system operators who would use the data to more precisely estimate load impacts under different conditions and at different times.
Metrics and Performance Indicators	Participation rates, system impacts, adoption rates, cost-effectiveness (customer)
Topic(s) addressed	Demand response
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development

Initiative 3.1.3 Assess iDERs and Load Management Systems

Description	Assess the load shapes and potential load control performance of specific common (or likely to become common) integrated distributed energy resources and load management systems, starting with those being marketed commercially.
Impact if Successful	Demand response technologies and strategies would be more widely adopted, because they would entail more desirable (less costly) customer actions, would be better incented, and address more technologies.
Primary Users and/or Beneficiaries	Small and medium-size customers, residential, commercial, industrial and agricultural with "typical" consumption needs, including those more likely to implement DR/DER approaches that are based on industry best practices and marketed in volume to reduce costs.
Metrics and Performance Indicators	Participation rates, system impacts, adoption rates, cost-effectiveness (customer)
Topic(s) addressed	Demand response market design
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development

Table 25: Ratepayer Benefits Summary For Sub-Theme 3.1

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 3.1.1 Pilot Test for the Next-Generation Demand Response Landscape	X	X		X	X		X	X	X
Initiative 3.1.2 Assess Performance of Load Control Systems	X	X		X	X		X	X	X
Initiative 3.1.3 Assess iDERs and Load Management Systems	X	X		X	X		X	X	X

Source: California Energy Commission

3.2 Enable Electric Vehicle-Based Grid Services

Plug-in electric vehicles (PEVs) are poised to increase in California with policymakers targeting 1.5 million zero emission vehicles on California roads by 2025.[78] PEVs will increase electricity demand, but they also offer unique opportunities for grid flexibility through vehicle grid integration (VGI).[79] Successful deployment and integration of PEVs will reduce California's dependence on petroleum, improve public health, reduce carbon emissions, and support California's economy.

A growing surplus of spent PEV batteries could also provide valuable services to the electric grid as second-use batteries, since about 70 percent of battery's charge capacity remains when it completes its primary life. A battery resale market could bring down the net cost of PEV ownership, which is high because of costly battery components such as lithium and cobalt.

THE CALIFORNIA VEHICLE-GRID INTEGRATION ROADMAP ESTABLISHES A RESEARCH AGENDA TO EFFECTIVELY USE A GROWING PEV POPULATION TO EXPAND THE ELECTRICITY GRID'S ABILITY TO COST-EFFECTIVELY HOST RENEWABLE ENERGY THROUGH BATTERY ENERGY STORAGE, WHILE POTENTIALLY REDUCING THE NET COSTS OF PEV OWNERSHIP.

CALIFORNIA ISO,
CALIFORNIA VGI ROADMAP[80]

Battery Second-Use

Research on battery second-use as energy storage has focused on technical attributes such as charge capacity and duration of second life. With these results, new research will be able to develop innovative battery management systems with battery charge capacity diagnostic technologies to more effectively assess battery life and lower repurposing costs.

Smart Charging

PEVs can serve as flexible loads by delaying their charging times or modulating their charge rates. This smart charging, also known as V1G, can make grid operation more efficient and reliable, but must be designed to compensate drivers and preserve mobility in diverse applications.

A state with 1.5 million PEVs needs charging stations as common and usable across brands of PEVs as gasoline stations are today. This becomes difficult if too many different groups of PEV manufacturers require different charger-to-car communication methods, yet that was the case until recently. EPIC is funding the demonstration of a common interoperability standard, ISO/IEC 15118. To date six car manufacturers have agreed to adopt it.[81] EPIC research projects are developing methods to translate grid load conditions and pricing rates to each PEV through open-source communication standards.

Bi-directional PEVs

Limited pilot projects have demonstrated bi-directional charging in the form of

78Governor Brown, Executive Order B-16-2012. March 23, 2012: 1.5 million zero emission vehicles by 2025

79 California Vehicle-Grid Integration Roadmap: Enabling vehicle-based grid services http://www.caiso.com/Documents/Vehicle-GridIntegrationRoadmap.pdf

80 California Vehicle-Grid Integration Roadmap: Enabling vehicle-based grid services http://www.caiso.com/Documents/Vehicle-GridIntegrationRoadmap.pdf

81 http://docketpublic.energy.ca.gov/PublicDocuments/16-TRAN-01/TN215326_20170113T100319_Stefa_Reinsdorf_OEM_Group_Comments_OEM_Consolidated_Comment_to.pdf

vehicle-to-grid (V2G) or vehicle-to-building (V2B). PEVs with bi-directional capability strategically charge when costs are low and discharge power back to the grid or to their own facilities when costs are high or to earn revenue by providing services such as frequency regulation. This capability can bring down the cost of PEV ownership. Bi-directional PEV charging promises to supplement stationary energy storage to achieve California's energy policy goals.

KEY TECHNICAL AND MARKET CHALLENGES

Effective vehicle-grid integration involves diverse actors whose actions must be coordinated and optimized. PEVs can fulfill electricity grid services similarly to stationary energy storage, but there are added challenges involving mobility and charge behavior that affect market integration and resource availability. Additionally, vehicle-grid integration will have to adapt as evolving technological capabilities may change personal transportation.

Communication connectivity enables rideshare services which may disrupt the traditional model of personal vehicle ownership, while improved urban planning should reduce the need for a personal car. PEV driving ranges and costs continue to improve, but bi-directional charging remains costly.

The introduction of autonomous, connected, electric and shared (ACES) vehicles could lower transportation energy intensity and the number of vehicles required to provide transportation services.[82] Differences in the daily operation of ACES versus conventional vehicles may make VGI more challenging. For example, ACES vehicles may spend significantly more time driving and less time charging, limiting availability for grid services. There may also be new or enhanced opportunities for ACES VGI for certain applications. ACES vehicles will require traffic flow awareness to optimize their trip scheduling and operation, and will benefit from cost-effective grid-friendly charging. Modeling interconnected dynamics between human mobility and power systems can serve as a platform for business models combining value streams from mobility and electricity system benefits. This platform of knowledge can benefit today's PEV business models and will be essential in enabling effective VGI for ACES vehicles.

This environment creates the need for actions on the following:

Lack of standard methodology for aggregating PEVs into larger, controllable resources

Conducting pilot tests and demonstrations of enhanced aggregation and market participation business models that address a variety of PEV use cases can improve the feasibility and cost-effectiveness of widespread smart charging and V2G. The Governor's 2016 ZEV Action Plan calls on state agencies to support "VGI pilots that help commercialize applications that aggregate vehicles as distributed energy resources, enhance communication, and control functionality between vehicle and grid infrastructure, and derive value for vehicles as flexible load and storage in grid support applications."[83] Widespread aggregation would enable PEV owners to earn revenue in electricity markets that require a large minimum resource size for participation.

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82 Autonomous taxis could greatly reduce greenhouse-gas emissions of US light-duty vehicles http://www.nature.com/nclimate/journal/v5/n9/nclimate2685/metrics/blogs

83 2016 ZEV Action Plan: An updated roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025 https://www.gov.ca.gov/docs/2016_ZEV_Action_Plan.pdf

California's Distributed Energy Resources Action Plan envisions PEV "charging systems, and mobility and driving behavior" that "can be predicted and overseen in grid operations."[84] EPIC demonstrations involving traffic flow awareness and bi-directional PEV functionality can contribute to new business models involving mobility, wholesale markets, the possible deployment of ACES vehicles, and benefits to the distribution system.

Cost of repurposing or remanufacturing PEV batteries for second-use applications

These costs are currently higher than manufacturing a new PEV battery. Additionally, the uneven degradation of the individual cells in the PEV battery make it difficult to cost effectively determine the viability of PEV battery cells for second-use applications. No streamlined, cost effective method exists to determine used PEV battery health at the cell level.

84 California's Distributed Energy Resources Action Plan: Aligning Vision and Action http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Organization/Commissioners/Michael_J._Picker/2016%20DER%20Action%20Plan%20FINAL.pdf

Table 26: Previous and Planned EPIC Investments on Electric Vehicle-Based Grid Services

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Smart Charging	Demonstration of Electric Vehicle Smart Charging to Support Grid Operational Needs (EPC-14-056) Smart Charging of Plug-in Electric Vehicles with Driver Engagement for Demand Management and Participation in Electricity Markets (EPC-14-057) Vehicle-Grid Integration in California Using the ISO/IEC 15118 Global Interoperability (EPC-14-077) Next-Generation Grid Communication for Residential PEVs (EPC-14-078) Open Source Platform For Plug-in Electric Vehicle Smart Charging (EPC-15-013)	Proposed agreements under GFO-16-303 Advanced Vehicle-Grid Integration Research and Demonstration: Improving Commercial Viability of Fast Charging by Providing Renewable Integration and Grid Services with Integrated Multiple DC Fast Chargers SCRIPT (Smart Charging Infrastructure Planning Tool) Demonstration of Vehicle-Grid Integration Under Non-residential Scenarios Advanced Transit Bus VGI Project
Bi-directional Power Flow (V2G)	Distribution System Aware Vehicle to Grid Services for Improved Grid Stability and Reliability (EPC-14-086) Communication Interface for Smart Electric Vehicle Services Research and Development (EPC-15-015)	Proposed agreements under GFO-16-303 Advanced Vehicle-Grid Integration Research and Demonstration: Open Vehicle to Building/Microgrid Integration Enabling ZNE and Improved Distribution Grid Services Adaptive Chargers for Delivery Customers Demonstrating California Advances in Charging Intelligent Electric Vehicle Integration (INVENT)
Battery Second Use (B2U)	No projects	Advanced VGI Control to Maximize Battery Life and Use of Second-life Batteries to Increase Grid Service and Renewable Power Penetration

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

EPIC will demonstrate additional pre-commercial smart charging applications to enhance aggregation and associated market opportunities. These activities will ensure that interoperable equipment and electricity market options are broadly available and acceptable to drivers. Integrating charge scheduling with traffic flow awareness and automated trip planning will create new business cases that improve the value of VGI and transportation services in general. To encourage V2G adoption, EPIC will work to reduce component costs for bi-directional capable PEVs.

EPIC will address battery second use cost by quantifying battery pack degradation in first-and second-use applications, developing tools to assess battery state of health, and predicting future battery degradation. Applied research in battery pack on-board diagnostics that monitor and record cell state of health history, both in PEVs and in energy storage systems, will support this assessment and reduce cost for second use applications.

Initiative 3.2.1 Grid-Friendly PEV Mobility

Description	This initiative will demonstrate advanced VGI functions to better characterize the business cases for emerging applications. Examples of emerging applications include VGI aggregation for public and private light- to heavy-duty fleets for transit and goods movement, and advanced fleet management functions. It will advance communication standards and control functionalities between PEVs and grid infrastructure, helping to expand aggregation capabilities and associated market opportunities. It will demonstrate the value of advancing technological platforms to incorporate traffic flow awareness and automated trip planning with VGI capabilities. It will also seek to reduce the marginal costs for bi-directional functionality for PEVs and charging stations so automakers will have increased confidence in the business case for producing and warranting bi-directional capable PEVs.
Impact if Successful	The most cost-effective smart charging and bi-directional VGI applications will accelerate PEV adoption. A robust ecosystem of third-party aggregators will maximize access of PEVs to electricity market revenue. Integrating charge scheduling with traffic flow awareness will improve utilization of existing transportation and grid infrastructure. It will expand PEV benefits and optimizing the grid integration of ACES vehicles. Bi-directional capable PEVs and charging stations will be widely available and deployed to fulfill grid service and energy security needs through V2G and V2B.
Primary Users and/or Beneficiaries	PEV owners and fleet operators; charging companies and third-party aggregators; electric utilities and the California ISO; regulators; facilities using PEVs as energy storage

Metrics and/or Performance Indicators	PEV services as a proportion of DER grid services • Driver and owner acceptance of smart / bi-directional VGI, number of participants revenue and market penetration of PEV / DER aggregators, including for bi-directional charging capabilities • Bi-directional cost differential for automakers and charging station manufacturers
Topic(s) addressed	Smart charging, bi-directional power flow
Value Chain	Demand-side Management Grid Operations/Market Design
Program Area(s)	Applied Research and Development Technology Demonstration and Deployment Market Facilitation

Initiative 3.2.2 Battery Second Use

Description	This initiative will develop battery monitoring technologies or test methods to better characterize and assess PEV battery cell condition to better inform PEV owners primary battery health and to optimize configuration of second-life PEV battery packs for maximum performance and capacity in second-life applications used to enhance grid reliability. This research will develop and demonstrate real-time monitoring and data logging that will lead to improved health and safety of high powered battery packs while also better enabling battery second-use repurposing strategies for grid storage applications such as reducing peak loads from DC fast charging.
Impact if Successful	This initiative could optimize primary and secondary use of the batteries (e.g., extending operation in primary applications) and improve the value proposition for repurposing batteries that have reached their end-of-useful life in PEV applications. The useful battery cells could be packaged into larger energy storage systems for grid-level or localized energy storage to provide grid stabilizing services.
Primary Users and/or Beneficiaries	Residential PEV owners, electric utilities
Metrics and/or performance indicators	• Cost effectiveness of second use battery, or other best use of components • Potential lifetime carbon footprint reduction • Reduced cost of PEV ownership • Resulting accelerated PEV market adoption

- Battery waste diverted from landfills
- Number or batteries repurposed

Topic(s) addressed	Battery Second Use (B2U)
Value Chain	Demand-side Management Transmission and Distribution
Program Area(s)	Applied Research and Development

Table 27: Ratepayer Benefits Summary For Sub-Theme 3.2

Initiative	**Promote Greater Reliability**	**Lower Cost**	**Increased Safety**	**Societal Benefits**	**GHG Emissions Mitigation and Adaptation**	**Lower Emission Vehicles/Transpo rtation**	**Economic Development**	**Public Utilities Code 740.1**	**Public Utilities Code 8360**
Initiative 3.2.1 Grid-Friendly PEV Mobility	X	X	X	X	X	X	X	X	X
Initiative 3.2.2 Battery Second Use	X	X		X	X	X		X	X

Source: California Energy Commission

3.3 Increase the Value of Distributed Energy Resources and Renewables to the Transmission and Distribution System

More than 4,500 MW of distributed solar PV is on homes and buildings throughout California, with that number expected to quadruple over the next decade as solar prices fall.[85,86] The electric grid serving those buildings is evolving from a centralized system where high-inertia generation sources ramp up and down to balance demand to a decentralized system where demand can be ramped up and down to balance increasingly variable renewable supply. Generation no longer has the inertia needed to keep power stable. The grid will have to handle increasing amounts of two-way power flows, creating safety challenges, so that high PV penetrations on many circuits will require adaptive protection and flexible operating control schemes. In addition, potential PV buyers whose planned systems hit the 15 percent trigger point of Rule 21 will have to pay for expensive interconnection studies or upgrades.

With improved forecasting and enabling technologies such as advanced inverters, the value of distributed PV to the grid will increase dramatically. A CAISO-NREL study finds "the development of advanced power controls can leverage PV's value from being simply an intermittent distributed energy resource to providing grid services that range from spinning reserves, load following, voltage support, ramping, frequency response, variability smoothing and frequency regulation."[87] Strategic placement of DERs, including PV and energy storage, will reduce the need for costly distribution system upgrades.[88]

With continuing research, smart inverter technology has advanced so that by September 2017 smart inverters will have to pass the UL 1741 SA test showing they can respond to abnormal grid operations by helping DERs adapt output and stabilize the grid.[89,90] Smart inverters are currently being tested for their ability to provide voltage regulation and control reactive power. With advances in grid telemetry and sensors, and with smart inverters and smart meters enabling two-way information exchange between utilities and consumers, it is now possible for grid operators to have access to near-real-time data measurement.

To enable a high-DER environment, the Federal Energy Regulatory Commission (FERC) designed and utilities have adopted interconnection agreements with small generators. The Rule 21 Smart Inverter Working Group hosted considerable discussions about inverter-grid communications protocols. Since 2016, regulations have ensured grid connection cost transparency. Distribution system planning analysis tools are beginning to include the functions required to support DER and perform integrated distribution planning.

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85 http://gosolarcalifornia.ca.gov/

86 http://docketpublic.energy.ca.gov/PublicDocuments/15-IEPR-03/TN207439_20160115T152221_California_Energy_Demand_20162026_Revised_Electricity_Forecast.pdf

87 Loutan, Clyde, and Vahan Gevorgian. 2016. "Using Renewables to Operate a Low-Carbon Grid: Demonstration of Advanced Reliability Services from a Utility-Scale Solar PV Plant." CAISO, NREL. http://www.caiso.com/Documents/UsingRenewablesToOperateLow-CarbonGrid.pdf.

88 Clean Coalition, "Locational Benefits of Distributed Generation," http://www.clean-coalition.org/site/wp-content/uploads/2013/11/Locational-Benefits-Brief-08_tk-6-Nov-2013.pdf

89 CPUC Decision 14-12-035

90 UL. 2016. "UL Launches Advanced Inverter Testing and Certification Program." Press Release. September 8. http://www.ul.com/newsroom/pressreleases/ul-launches-advanced-inverter-testing-and-certification-program/.

"MOST OF THE NEW DISTRIBUTED ENERGY RESOURCES…ARE LOCATED IN THE LOWER VOLTAGE DISTRIBUTION GRID, CLOSE TO CONSUMERS. THIS GRID WAS DESIGNED FOR ONE WAY POWER FROM CENTRAL GENERATION RESOURCES, AND MUST BE REBUILT TO MEET THE NEEDS OF A MORE DYNAMIC FLOW FROM TWO DIRECTIONS. FURTHERMORE, DISTRIBUTED ENERGY RESOURCES PLACED CAREFULLY IN SPECIFIC LOCATIONS CAN AVOID (TEMPORARILY, AT LEAST) EXPENDITURES FOR NEW HARDWARE SUCH AS TRANSMISSION OR SUBSTATIONS."

COMMISSIONER PICKER, CALIFORNIA PUBLIC UTLITIES COMMISSION[91]

KEY TECHNICAL AND MARKET CHALLENGES

Renewable generation and DERs added to California's electricity system in the future must include technology advances, and be efficiently planned and managed, to benefit the grid and the environment while keeping costs low for consumers, especially for those in disadvantaged communities. Currently, grid operators cannot predict with sufficient accuracy how different weather patterns or other conditions will affect the energy production or consumption of the rapidly growing number of DERs on California's grid.

For variable renewables and DERs to benefit rather than put greater pressure on California's electricity grid, the following barriers need to be addressed:

Optimize and coordinate smart inverters using advanced communication and control capabilities

By the end of 2020, the CPUC plans to fully operationalize advanced inverter functions to allow DERs to provide grid services in response to utility signals.[92] Most of these grid services require the inverter to decrease real power provided to the grid. Further research is needed to show how utilities can operate the distribution grid coordinating the new phase three advanced functions of inverters to maximize the renewable power from distributed generation while protecting distribution equipment and power quality.

Distribution Energy Resource Management Systems (DERMS), which monitor, optimize, and dispatch DERs to meet grid and market needs, may be used to optimize smart inverters functions.[93] In their proposed *EPIC 2018 – 2020 Investment Plan*, the IOUs are working on DERMS to use with demand response, electric vehicles, and the phase one smart inverter function of Volt/VAR optimization. Further research is needed to establish DERMS algorithms that make use of smart inverter phase three functions to maximize the production of renewable power while maintaining grid stability.[94]

Reduce the cost and time needed for interconnection to the grid and improve interoperability

FERC-inspired interconnection agreements do not address how coordination between the grid and the DERs should be accomplished. There is a need for improved distribution modeling that shows the per phase dynamic hosting capacity impacts

91 http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/About_Us/Organization/Commissioners/Michael_J._Picker/2017talk.pdf

92 DER Action Plan, Action Element 2.9

93 DERMS are systems that monitor, optimize, and dispatch DERs to meet grid and market needs.

94 DER Action Plan, Action Element 2.6 calls for the CPUC to begin to consider the role of DERMS to "enhance grid management and maximize the value of DER deployment" by the end of 2017.

from DER to facilitate interconnection. The CPUC plans to consider use of the Integrated Capacity Analysis (ICA) being developed as part of its Distributed Resource Plan (DRP) proceeding "to streamline utility interconnection processes to accelerate DER deployment" by the end of 2018.[95] However, this only identifies where projects can be fast-tracked and where more detailed studies may be required. The ICA methodologies are a balance between accuracy of results and computational time requirements. Because the accuracy is highly dependent on the complexity of the distribution system, current methodologies provide sub-optimal ICA results that may require further burdensome impact studies for interconnection. Improving the iterative methodology will reduce the need for additional impact studies.

In addition, the ICA will only determine the maximum amount of DER that can be interconnected without the need for in-depth impact studies. The ICA does not model optimal DER locations. The DRP's Locational Net Benefits Analysis (LNBA) will determine the location-specific benefits of DER projects, but these benefits are restricted to those that are beneficial to the IOU, such as deferral of distribution grid improvements. Other benefits, such as maximizing renewable energy production and value to consumers, will not be the focus of LNBA. Improving distribution modeling will reduce the need for studies by improving the understanding of optimal locations for DER interconnection, thus streamlining utility interconnection applications and lowering costs.

Advance distribution planning tools

A goal of the future electric grid identified in the DOE's Grid Modernization Initiative is to "develop and disseminate new and improved models for analysis, management and optimization of grid performance."[96] Large scale deployment of DERs is hampered by an inability to accurately model their effects or to quantify their potential benefits. Current design and planning tools for the electric grid rely on simplified power engineering formulas and assumptions, such as static, balanced loads and generators. This will not suffice to address dynamic DER impacts on feeders and ensure smart inverters and other smart grid equipment work to maintain voltage within acceptable limits (volt-var control), in lieu of costlier traditional grid upgrades. Improving the planning tools could move their application from simple analysis to providing an understanding of how to increase the system's capacity for DERs at the lowest cost. This work will build upon current activities under the Energy Commission's *EPIC 2015 – 2017 Investment Plan* to develop and advance an open source modeling tool to enable greater data sharing and transparency, including investigating the use of a common information model in International Electrotechnical Commission (IEC) 61970 and 61968 standards.

Modeling under the second investment plan focused on visualization of California's future, "smart" distribution system. Future modeling efforts must focus on optimizing the distribution system to maximize the production of renewable energy from DERs and provide the greatest benefits, particularly to those in disadvantaged communities, at the lowest cost to ratepayers.

95 DER Action Plan, Action Element 2.7.

96 Department of Energy, *Grid Modernization Multi-Year Program Plan*. 2015. https://energy.gov/sites/prod/files/2016/01/f28/Grid%20Modernization%20Multi-Year%20Program%20Plan.pdf, page 12

Improve forecasting of DER energy production and the effects of DERs on load under varying conditions.

The impacts of higher levels of DERs on net load are currently difficult to predict. DER production and consumption is not typically visible to grid operators. In addition, the effect of different conditions, such as temperatures and weather patterns, on gross energy consumption and DER production is not well understood, because grid operators only see the net load. There is little insight into the impact of different components that make up the net load curve. Forecasters and grid operators cannot adequately predict how increases in DERs on the grid, energy efficiency improvements, and other factors will affect the net load.

Table 28: Previous and Planned EPIC Investments on Transmission and Distribution

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Smart Inverters	Assessing the Ability of Smart Inverters and Smart Consumer Devices to Enable more Residential Solar Energy (EPC-14-079) Smart Inverter Interoperability Standards and Open Testing Framework to Support High-Penetration Distributed Photovoltaics and Storage (EPC-14-036) Demonstration of Integrated Photovoltaic Systems and Smart Inverter Functionality Utilizing Advanced Distribution Sensors (EPC-14-035)	Solar +: Taking the Next Steps to Enable Solar as a Distribution Asset (GFO-16-309)
Interconnection and Interoperability	Certified Open-Source Software to Support the Interconnection Compliance of Distributed Energy Resources (EPC-15-044)	No current or planned investments
Communication and Controls	Substation Automation and Optimization of Distributed Circuit Operations (EPC-15-086) Developing a Distribution Substation Management System (EPC-15-046) Integrated Distributed Energy Resources Management System (iDERMS) (EPC-15-090) Meeting Customer and Supply-side Market Needs with Electrical and Thermal Storage, Solar, Energy Efficiency and Integrated Load Management Systems (EPC-15-074) UniGen Smart System for Renewable Integration (EPC-15-059)	Develop Open-Source Electricity System Tools and Models to Visualize and Operate California's Distribution Systems 3rd Qtr. CY 2017
Distribution Planning Tools	No projects.	Develop Open-Source Electricity System Tools and Models to Visualize and Operate California's Distribution Systems 3rd Qtr. CY 2017 Solar +: Taking the Next Steps to Enable Solar as a Distribution Asset (GFO-16-309)
Renewables Forecasting	High-Fidelity Solar Power Forecasting Systems for the 392 MW Ivanpah Solar Plant (CSP) and the 250 MW California Valley Solar Ranch (PV) (EPC-14-008) Improving Solar & Load Forecasts: Reducing the Operational Uncertainty Behind the Duck Chart (EPC-14-001) Solar Forecast Based Optimization of Distributed Energy Resources in the LA Basin and UC San Diego Microgrid (EPC-14-005) Improving Short-Term Wind Power Forecasting through Measurements and Modeling of the Tehachapi Wind Resource Area (EPC-14-007)	Solar +: Taking the Next Steps to Enable Solar as a Distribution Asset (GFO-16-309)

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

To ensure a reliable and cost-effective transition to a high-renewable, high DER grid, EPIC will take a multi-pronged approach. EPIC will fund demonstrations of advanced smart inverter functionality optimization to determine how this functionality can be used to maximize renewable generation on the grid while improving power quality and reliability. It will fund improvements in modeling of grid hosting capacity to reduce the need for individual interconnection studies, helping to streamline utility interconnection applications and lower costs. Distribution planning will improve with better EPIC-funded tools that serve ICA and LNBA to demonstrate which DER investments will provide the greatest benefit to ratepayers and those in disadvantaged communities. Distribution planning tools will also accommodate rapid and complex interactions between all parties and resources. This will reduce the need for costly investments in traditional grid stabilizing hardware such as transformer load tap changers, voltage regulators, and capacitors. Studies of how weather patterns and other events impact diverse DER uses including vehicle charging will help forecasters predict variable net load and balance it with utility-side generation. More detailed wind and solar forecasting will help grid operators ensure generation throughout variable weather conditions without forcing curtailment.

Initiative 3.3.1 Optimize and Coordinate Smart Inverters Using Advanced Communication and Control Capabilities

Description	This initiative will improve the ability of solar PV to benefit the grid and ratepayers by optimizing the functionality of smart inverters. Advanced smart inverter functionality will enable rooftop PV to respond to signals from a utility or other grid operator to improve power quality and reduce the chance of electricity outages. Smart inverters also increase the amount of solar PV that can be installed on the distribution grid without upgrades to grid equipment. The use of advanced smart inverter functions will reduce the real power provided to the grid by rooftop PV. This initiative will develop DERMS algorithms to optimize the settings and coordination of advanced smart inverters to maximize the output of solar generation on the grid while maintaining reliability and power quality.
Impact if Successful	This initiative will enable smart inverters to provide grid services without excessively reducing the amount of renewable generation from rooftop PV that is exported to the grid. This reduces GHG emissions from California's power mix and maintains revenues for DER owners for providing renewable generation.

Primary Users and/or Beneficiaries	Utilities, smart inverter manufacturers, DER owners and service providers, researchers, and third-party aggregators
Metrics and/or Performance Indicators	Maintenance of power quality Maintenance of grid reliability Increase in output of rooftop PV generation over business as usual Quantify the value streams for ancillary services
Topic(s) addressed	Smart inverters
Value Chain	Transmission Distribution
Program Area(s)	Applied Research and Development Technology Demonstration and Deployment

Initiative 3.3.2 Advance Distribution Planning Tools to Reduce the Cost and Time Needed for Interconnection to the Grid and Improve Interoperability

Description	Build on the outcomes of modeling funded under the second investment plant to improve distribution modeling within a framework that includes Distributed Energy Resource Management Systems. This activity will enhance modeling tools to coordinate and optimize DERs on the grid, and increase DER use in disadvantaged communities for the benefit of ratepayers. This research will explore methods to improve and speed up calculations for studies such as Integrated Capacity Analysis and finding optimal locations for DERs, determining impacts and operations of smart inverters, and to facilitate interconnection.
Impact if Successful	Results from this initiative could be used to increase DER deployment and lower costs, both statewide and within disadvantaged communities and will reduce the need for individual interconnection studies, thus streamlining utility interconnection applications and lowering costs.
Primary Users and/or Beneficiaries	Utilities, regulators, policymakers, DER owners and aggregators, CPUC
Metrics and Performance Indicators	Reduction of individual interconnection studies by the utilities Faster utility interconnection applications Lower interconnection fees
Topic(s) addressed	Distribution Planning and Modeling

Value Chain	Distribution
Program Area(s)	Applied Research and Development

Initiative 3.3.3 Provide Visibility into Load and DER Responses to Weather and Other Variables and into the Effects of DER on Gross Load

Description	This initiative will provide enhanced tools for grid operators to visualize the effects of weather patterns and other events on rooftop solar production, electric vehicle charging, and other DER usage, as well as on the gross load. The establishment of a comprehensive database of DER production and gross load data, and improved forecasting tools that make use of the database, will enable forecasters to better predict the net load that will need to be met through geothermal, natural gas, and other utility-scale generation.
Impact if Successful	An improvement in the ability of the CAISO and other grid operators to forecast the net load and determine reserves that will need to be scheduled to meet the predicted demand, particularly in cases of heat waves and other atypical events.
Primary Users and/or Beneficiaries	CAISO, CPUC, Utilities, DER owners and aggregators
Metrics and Performance Indicators	Improvement in net load forecasting accuracy Reduction in large errors in net load forecasts Database of DER production and consumption data, with regional granularity and time, weather, and other variables.
Topic(s) addressed	Renewables Forecasting
Value Chain	Generation Demand-Side Management
Program Area(s)	Applied Research and Development Technology Demonstration and Deployment

Table 29: Ratepayer Benefits Summary For Sub-Theme 3.3

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 3.3.1 Optimize and Coordinate Smart Inverters Using Advanced Communication and Control Capabilities	X	X			X			X	X
Initiative 3.3.2 Advance Distribution Planning Tools to Reduce the Cost and Time Needed for Interconnection to the Grid and Improve Interoperability	X	X	X	X	X			X	X
Initiative 3.3.3 Provide Visibility into Load and DER Responses to Weather and Other Variables and into the Effects of DER on Gross Load	X	X		X	X			X	X

Source: California Energy Commission

3.4 Defining and Demonstrating the Locational Benefit and Best Configuration of Grid-Level Energy Storage as the California Grid Transitions to More Distributed Energy Resources

Grid-level (utility or ISO controlled) energy storage at the transmission, distribution, and aggregated customer levels offers unique flexibility for ensuring smooth operation of a renewables-heavy grid. It can help utilities balance variable generation and demand; control frequency, voltage, and other power quality features; and black start the grid after power disruptions. By locating storage at transmission constrained points, utilities will be able to reduce grid congestion, defer or avoid costly investments in new transformers, and make the grid "more secure, reliable, and responsive."[97] Midday over-generation that threatens to curtail renewables and steep afternoon ramps can be replaced by a gentler slope where energy stored midday or earlier is released in the late afternoon.

AB 2514 (Skinner, 2010) and AB 2868 (Gatto, 2016) directed the CPUC to set storage deployment targets, which the CPUC determined through a public process should total 1.825 GW of procured storage for IOUs by 2020 (installed by 2024). The leak at the Aliso Canyon underground natural gas storage facility, the closure of the 2.2 GW San Onofre Nuclear Generating Station in 2013, and the planned closure of 2.3 GW Diablo Canyon Nuclear Plant in 2025 are driving the need for additional grid-level energy storage.

With increasing storage procurement, costs of storage resources are coming down. "Although in its formative stages, the energy storage industry appears to be at an inflection point, much like that experienced by the renewable energy industry around…eight years ago," writes one financial analyst.[98] Storage technology development continues to show great variety in storage types, sizes, durations, and features. At the grid level, PG&E is studying the economic feasibility of a large Compressed Air Energy Storage (CAES) system using a depleted natural gas reservoir to hold the compressed air.[99] Emerging advanced rail energy storage technology was proposed at a California Bulk Energy Storage Workshop. Various CAES, battery and flywheel technologies have been piloted, some on military installations, others funded by the Energy Commission under EPIC or prior to EPIC. An Energy Commission co-funded sodium sulfur battery at the PG&E Vaca-Dixon facility was the first battery system to provide services to CAISO markets, according to the agency California storage roadmap.[100]

KEY TECHNICAL AND MARKET CHALLENGES

Investors need to know whether market values of storage services will compensate for the typically high capital costs associated with storage technologies, but lack information about performance, partly because of limited operational experience. Long lead times accentuate financial risks for bulk storage technologies like CAES,

97 Gyuk I, Johnson M, Vetrano J, Lynn K, Parks W, Handa R, et al. Grid energy storage, Technical Report. U.S. Department of Energy, 2013

98 George Bilicic, Vice Chairman and Global Head of Lazard's P. Ower, Energy & Infrastructure Group. Lazard's LCOE, op cit.

99 Doughty, C., Kelly L., and Mathias, J, Bulk Energy Storage in California, CEC-200-2016-006, California Energy Commission, 2016

100 Advancing and Maximizing the value of Energy Storage Technology, A California Roadmap, December 2014.

already limited by geographic constraints and a slow, uncertain permitting process. To make storage investments cost effective, grid planners need to choose the best locations, sizes and types of grid-level energy storage deployment, but lack the detailed tools and necessary software to do so. This creates the following opportunities for R&D.

Demonstrate the value of advanced energy storage technologies

Safer and more cost-effective energy storage options need to be developed for integration into the electrical grid with input from the electric utilities. Under the *EPIC 2012 – 2014 Investment Plan*, the Energy Commission funded seven projects to test and demonstrate the value, operational safety, and commercial potential of different emerging energy storage technologies. EPIC awardees typically work with IOUs in integrating these storage systems with traditional utility infrastructure. For example, under EPIC funding, Eos is pilot testing an AC-integrated energy storage system using its Eos Znyth battery modules in collaboration with PG&E. System performance is being characterized against a variety of use cases, including peak shaving, ancillary services, and frequency regulation. Eos is also modeling a portion of PG&E's distribution network to create simulated grid conditions that will allow for dynamic testing of the battery's impacts on the electricity grid.

EPIC awardees experienced challenges in technical hurdles, long wait times to obtain permits and interconnection agreements, and difficulties in determining the most beneficial uses of the technology. These challenges are the same challenges identified in the State's Energy Storage Roadmap.[101] To address these issues, new methods need to be developed, tested, and validated to improve the cost-benefit value of grid-level energy storage systems.

Enhance energy storage valuation and optimization tools for energy storage installations

Potential storage investors can be challenged on what storage to choose and how to implement it. A 2013 DOE grid energy storage report lamented the absence of numerous functionalities on existing energy storage planning and design tools, including sizing, siting, and validation of the proper functioning grid-storage interactions.[102] Methods for quantifying the value of energy storage are also not well established, presenting a market barrier for investments required for broad energy storage deployment. A validated and publicly available tool is needed to support transparent decisions on optimizing the value of energy storage system to electricity ratepayers and other stakeholders. Under EPIC funding, the Electric Power Research Institute (EPRI) developed and delivered a web-hosted free public software tool, StorageVET, to help individual storage adopters choose the most cost beneficial storage technology (as a stand-alone or aggregated with other distributed resources, such as solar PV), size, location and usage.[103,104] Usage includes, how much to cycle a battery, impacting its lifetime, given the values it provides in energy arbitrage and ancillary service sales. This tool is limited to a pre-determined energy storage location on the grid (transmission-connected storage, distribution-connected storage, and customer-sited storage) and cannot assess the overall and cannot assess

101 Ibid.

102 Gyuk I, Johnson M, Vetrano J, Lynn K, Parks W, Handa R, et al. Grid energy storage, Technical Report. U.S. Department of Energy, 2013

103 Storage Value Estimation Tool. www.storagevet.com

104 Kaun B. 2017, Validated and Transparent Energy Storage Valuation and Optimization Tool, California Energy Commission, CEC-500-2017-016

the overall need of storage on the grid or provide guidance on where the best location to site grid-level energy storage assets.

Table 30: Previous and Planned EPIC Investments on Grid-Level Energy Storage

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Compressed Air Energy Storage	High Temperature Hybrid Compressed Air Energy Storage (HTH-CAES) (EPC-14-027)	Demonstrating the Commercial Business Case for Microgrids that Supports California's Aggressive Energy and GHG Reduction Policies and Integrates New and Emerging Technologies – Energy Storage will be integral in moving microgrids/storage closer to commercialization (2017 Anticipated Solicitation)
Flywheels	A Transformative Flywheel R&D Project (EPC-15-016)	Demonstrating the Commercial Business Case for Microgrids that Supports California's Aggressive Energy and GHG Reduction Policies and Integrates New and Emerging Technologies – Energy Storage will be integral in moving microgrids/storage closer to commercialization (2017 Anticipated Solicitation)
Batteries	Utility Demonstration of Zynth Battery Technology to Characterize Performance and Grid Benefits (EPC-14-023) Pilot Testing of Eos' Znyth Battery Technology in Distributed Energy Storage Systems (EPC-15-018)	Demonstrating the Commercial Business Case for Microgrids that Supports California's Aggressive Energy and GHG Reduction Policies and Integrates New and Emerging Technologies – Energy Storage will be integral in moving microgrids/storage closer to commercialization (2017 Anticipated Solicitation)
Storage Planning	Energy Storage Valuation and Optimization Tool (EPC-14-019)	No current or planned investments
Alternative, Small-Scale Pumped Hydro Storage	Electricity Pumped Storage Systems Using Underground Reservoirs: A Feasibility Study for the Antelope Valley Water Storage System (EPC-15-049) Advanced Renewable Energy Storage and Recycled Water Project (EPC-15-079)	Demonstrating the Commercial Business Case for Microgrids that Supports California's Aggressive Energy and GHG Reduction Policies and Integrates New and Emerging Technologies – Energy Storage will be integral in moving microgrids/storage closer to commercialization (2017 Anticipated Solicitation)

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

As utilities and their ratepayers invest in increasing amounts of energy storage, it becomes essential to select storage options that are cost-effective and serve renewable and greenhouse policy goals. As the state implements AB 2514 and AB 2868, it is important to have confidence that the energy storage systems procured and sited under these policies be located where the maximum benefit can be obtained. Locations, storage sizes and features, costs, and grid needs must all be understood and acted upon. The proposed funding initiatives will focus on analysis and studies that assess different configurations of storage, recommend optimal configurations of storage, and provide policy makers and the utilities a better understanding of what targets to set for each use case and how to evaluate the locational value of these grid-level energy storage assets.

Initiative 3.4.1 Assessment and Simulation Study of the California Grid with Optimized Grid-Level Energy Storage

Description

This initiative will focus on analysis and detailed studies that provide insights into the future needs for grid-level energy storage connected to the distribution or transmission grid and managed or controlled by utilities, the CAISO or the third-party owners executed power purchase agreement with IOUs or CAISO.

The effort will establish a baseline assessment of the grid-level energy storage systems available on the California grid. It will create a database and informational materials on grid-level energy storage systems for use cases laid out by AB 2514, AB 2868, IOUs' procurement plans, and any later legislation or CPUC rulings. The analysis will include the collection of available data on the field performance of different installed grid-level energy storage technologies to: 1) determine how the varied technologies are performing, 2) assess the value or need for different durations of grid-level energy storage capabilities to support the key functions of the grid, and 3) evaluate how the power grid benefits from the integration of grid-level energy storage systems. The effectiveness and value of using grid-level energy storage systems will be assessed for meeting wholesale and distribution system needs as defined by the CPUC, IOUs, and CAISO perspective.

This initiative will fund a comprehensive and complex simulation study that can model, validate, test, simulate, and analyze the impact of grid-level energy storage installations on California's power grid. It will identify where grid-level energy storage could provide the greatest benefits, and what optimum capacity targets are to be set for procurement. The simulation study will provide valuable information on which combinations

	of different energy storage technologies provide the best value in relationship to the grid's stability while assessing performance and duration of the energy storage in stochastic and dynamic modes. It will also assess operational characteristics of the grid given existing and proposed procurement targets and evaluate locational values, operational values, and capacity values of energy storage. It will consider the impacts of grid congestion, and will address the amount of GHG emission reductions produced under different grid-level energy storage configurations. It will take into account other flexibility options such as automated demand response, classic peaker plant operations, aggregated DER services and other grid-level energy services that become available to the utilities and CAISO.
Impact if Successful	This simulation study will provide valuable information on which combinations and locations of grid-level energy storage provide the best value in relationship to grid stability and operation, while assessing the performance and duration of the grid-level energy storage in stochastic and dynamic modes. It will provide new insights into the implementation of the energy storage policies, allowing for the most cost-effective choices for ratepayers. This initiative will provide energy storage stakeholders institutional knowledge, field experience, and special insight into where and how much storage expansion is justified based on California grid needs and the performance and costs of grid-level energy storage systems. The simulation study will create a robust analysis tool that characterizes grid benefits, including the value of different grid-level energy storage technologies for multiple grid services. This will facilitate industry acceptance and help policy makers understand energy storage as a viable solution for higher penetration of renewable energy, multiple energy storage grid services, flexible grid operation, and GHG emission reductions.
Primary Users and/or Beneficiaries	CPUC, California ISO, Energy Commission, DOE, utilities, independent power producers, energy storage developers, vendors, service providers, national labs, industry associations, researchers, and policy makers
Metrics and/or Performance Indicators	Use and adoption of analysis and framework produced by the simulation study by stakeholders in California

	Wider integration of grid-level energy storage systems in resource planning at the grid level Broad deployment of grid-level energy storage to enhance renewable energy penetration and contribute to the grid flexibility, resiliency, and reliability
Topic(s) addressed	Energy Storage Simulation Study
Value Chain	Grid Operations/Market Design
Program Area(s)	Applied Research and Development

Table 31: Ratepayer Benefits Summary For Sub-Theme 3.4

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 3.4.1 Assessment and Simulation Study of the California Grid with Optimized Grid-Level Energy Storage	X	X	X	X	X			X	X

Source: California Energy Commission

CHAPTER 5
Theme 4: Increase the Cost-Competiveness of Renewable Generation

California has seen significant growth and cost reductions in renewable generation the past several years as a result of technology improvements and supportive policies such as the Renewables Portfolio Standard and California Solar Initiative. In-state renewable capacity has tripled between 2001 and 2016, and "the most dramatic change is the addition of utility-scale, solar photovoltaic power plants, especially between 2010 and 2015 when installed capacity rose from roughly 40 MW to 5,700 MW."[105] Most studies have found the utility-scale solar will achieve cost parity with conventional electricity sources by 2020.

"CONVERSATIONS WITH SOME INSTALLERS SUGGEST…FEWER EARLY MOVER CUSTOMERS REMAIN, AND THIS CHALLENGE IS LIMITING GROWTH, ESPECIALLY IN CALIFORNIA."
SOLAR ENERGY INDUSTRIES ASSOCIATION[106]

Despite this progress, continuing to grow California's renewable generation market to meet the new RPS targets and beyond will be challenging. Most of the significant progress in renewable energy has been limited to land-based utility-scale wind, utility-scale solar PV and rooftop solar PV. Even with continued cost reductions in these market sectors, maintaining their current growth rate in California will become difficult. Prime resource locations within the state become fewer, the costs to integrate these variable resources into the grid become greater, and the market for rooftop PV begins to saturate.

For renewable generation to expand in California at or above its current rate, technology advancements are needed that can open up new market opportunities for renewables. This theme describes funding initiatives that seek to:

Increase the economic potential of renewables in California

A number of constraints – including capital cost, land use, resource, aesthetics, logistics and infrastructure – currently limit locations within the state where renewables can be deployed. New technologies can be designed and developed within the boundaries of these constraints in ways current technologies cannot. These new technologies can potentially enable renewables to be deployed to new locations within the natural and built environments.

"NEW TECHNOLOGIES WITH NO ADVERSE EFFECTS ON ECOSYSTEMS WOULD UNLOCK FURTHER AREAS WHERE THAT TECHNOLOGY COULD BE DEPLOYED"
DEPARTEMNT OF ENERGY, SECOND INSTALLMENT OF THE QUADRENNIAL ENERGY REVIEW[107]

105 http://docketpublic.energy.ca.gov/PublicDocuments/16-IEPR-01/TN216281_20170228T131538_Final_2016_Integrated_Energy_Policy_Report_Update_Complete_Repo.pdf
106 http://www.seia.org/research-resources/solar-market-insight-report-2016-q3

107 https://www.energy.gov/sites/prod/files/2017/02/f34

Enable renewables to compete in grid service markets

Variable solar PV and wind is creating demand for flexible generation. Renewables such as geothermal and CSP have the potential to provide these grid services. However, further technology advancements are needed to enable renewables to meet the technical specifications and cost targets to compete in markets for grid services.

Develop technologies whose unique attributes can create new uses and markets for renewables.

Certain renewable technologies, such as solar PV, have no moving parts and can be designed in novel form factors. These and other attributes can help create a wider range of applications and increase market demand for renewables. Technologies with the potential to enable new applications and markets either have low penetrations or are still in their nascent stages

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/Quadrennial%20Energy%20Review--Second%20Installment%20%28Full%20Report%29.pdf

4.1 Advance Emerging Thin-film PV Technologies for High Value Applications

The electricity system has evolved in the past decade into a more decentralized system with the widespread integration of DER. This development served as an impetus for various thin-film photovoltaics to emerge. Although there are exciting developments for several emerging PV technologies, silicon remains the dominant commercial photovoltaic technology and accounts for over 85 percent of solar technologies on the market.[108] A recent report indicates that each doubling of solar energy production resulted in a 20 percent reduction in the price of crystalline-silicon photovoltaics (c-Si-PV).[109] If the trend continues, the prices for residential, commercial, and utility-scaled silicon-based photovoltaics will reach the SunShot 2020 targets. Declining costs for a single c-Si solar module and continuing incremental improvements to silicon-based technology will likely carry the PV industry in the foreseeable future.

However, further cost reduction and efficiency advancements for current Si-PV technologies are limited due to the properties of crystalline silicon. For example, the production of c-Si PV modules involves complex and energy-intensive manufacturing steps. Also, a low intrinsic light absorption of crystalline silicon requires thick and rigid wafers that are typically encapsulated in heavy glass. These limitations significantly impact the balance-of-system (BOS) costs.[110]

> “WHAT WE NEED IS A CELL THAT PERFORMS JUST AS WELL BUT IS THINNER, FLEXIBLE, LIGHTWEIGHT, AND EASIER TO TRANSPORT AND INSTALL”
>
> PROF. BULOVIĆ, MIT[111]

Processing of materials for the next-generation thin-film PV modules does not require energy-intensive production steps (e.g. electrodeposition, sol-gel based methods, spray coating, processing from solution). The emerging thin-film PV technologies have a light weight and feature the ability to be formed into many different shapes/colors/ transparencies and have the potential to be installed on a wider range of surfaces and roof types. These attributes promote the establishment of new high value applications that are not possible with standard c-Si PV systems.

Emerging thin-film technologies range in maturity from fundamental materials R&D to early commercialization, but have not been deployed at large scale. Large scale application of thin-film PVs would expand the technical potential of renewables in California and augment decarbonization of electricity system helping achieve SB 32 and SB 350 targets.[112,113]

R&D efforts in thin film have focused on efficiency and material science to help drive large scale adoption and commercialization.

Efficiency has been one of the major cost drivers for PV systems and it has continuously increased for both non-

108 M. Green, “Commercial progress and challenges for photovoltaics“, Nature Energy Vol. 1, 2016. DOI: 10.1038/nenergy.2015.15
109 Current and Future Costs of Photovoltaics: Long-term Scenarios for Market Development, System Prices and LCOE of Utility-scale PV Systems, Fraunhofer ISE, 2015. http://go.nature.com/3k9Jad
110 N. Stauffer, “Silicon and beyond”, MIT, 2015.

111 https://science.mit.edu/news/study-assesses-solar-photovoltaic-technologies
112https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB32
113https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350

flexible crystalline silicon PV modules and flexible thin-film PV modules.

Recent advancements in material science have demonstrated that thin-film PV cells can reach efficiencies higher than or comparable to c-Si PV while keeping the advantages from lower-cost manufacturing techniques.[114] Other thin-film PV technologies use materials that can be synthesized from non-toxic, abundant and affordable elements, but have not reached the 20 percent efficiency mark yet.[115]

Latest research initiatives supported improvement in the area of light management, such as enhancement of light trapping in the active area of the cell by applying concentrating devices (although such technologies aren't available for thin-film PVs yet). Novel materials architectures, using nanophotonic concepts have been tested to reduce reflection and parasitic absorption of solar flux.

> "NEW THIN-FILM PV TECHNOLOGIES OFFER POTENTIALLY UNIQUE DEVICE-LEVEL PROPERTIES THAT COULD OPEN THE DOOR TO NOVEL APPLICATIONS FOR SOLAR PV."
> MIT STUDY,
> THE FUTURE OF SOLAR ENERGY[116]

Emerging photovoltaics materials have drawn attention recently and achieved many significant milestones. R&D focused on developing advantageous characteristics of thin-film PVs without compromising on efficiencies and lifetimes will increase their competitiveness with other forms of renewable generation and enhance their position in the renewables portfolio.

KEY TECHNICAL AND MARKET CHALLENGES

Despite the advancements described, emerging thin-film PV technologies still have not achieved widespread adoption contrary to market-dominating commercially mature c-Si-PV technology.

The technical challenges for thin-film PV adoption and scale-up include needed efficiency, reliability, stability, toxicity, and reliance on scarce raw materials. In addition to the material science research, the thin-film products need to be designed to meet the specifications of these high-value applications most notably building integrated applications. Thin-film production must also be able to fit into existing manufacturing and supply chain channels to avoid the need for large capital expenditures.

114 >28 percent in gallium arsenide, > 20 percent in indium phosphide, copper-indium-gallium selenide, cadmium telluride, lead-based perovskites. For additional information see A. Polman et al., Photovoltaic materials: Present efficiencies and future challenges", Science 352, aad4424-9 (2016). DOI: 10.1126/science.aad4424

115 12 percent in copper-zinc-tin-sulfide, 11 percent in dye-sensitized titanium oxide and organic cells, 10 percent in monocrystalline silicone. For additional information see S. Rao et. al., "Emerging Photovoltaics: Organic, Copper Zinc Tin Sulphide, and Perovskite-based Solar Cells", J. Appl. Chem., 2016. DOI: 10.1155/2016/3971579

116 http://energy.mit.edu/wp-content/uploads/2015/05/MITEI-The-Future-of-Solar-Energy.pdf

> "COMMERCIAL THIN-FILM PV TECHNOLOGIES COMPETE WELL ON MODULE COST, BUT THEIR LOWER EFFICIENCIES MAY INCREASE OVERALL SYSTEM COST. FURTHERMORE, THE RELIANCE OF SOME THIN-FILM TECHNOLOGIES ON RARE AND TOXIC ELEMENTS MAY CREATE MATERIALS ISSUES THAT IMPEDE THEIR ABILITY TO SCALE."
>
> MIT STUDY,
> THE FUTURE OF SOLAR ENERGY[117]

A key non-technical requirement driving thin-film PV adoption is identifying unique, high-value market niches for grid connected and off grid applications.

Grid-connected applications include structures with unique form factors such as roof tiles and building walls and/or low-load bearing abilities such as windows and membrane roofs that prohibit standard c-Si PV use. Off-grid applications for thin-film PV technology include portable devices such as smartphones and the top of EVs, buses, and RVs.

The Energy Commission is working with Navigant Consulting to identify possible high-value applications for thin-film beach-head markets.

R&D focused on advancing emerging thin-film PV technologies will extend their application range and add value to PV technologies while enabling levelized cost-of-energy (LCOE) equivalence between PV systems and conventional sources of electricity.

117 Ibid.

Table 32: Previous and Planned EPIC Investments on Photovoltaic Technology

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Enhance Efficiency and Environmental Performance in Low-Cost PVs	High-Performance Cu-Plating for Heterojunction Silicon Cells, Based on Ultra-Low-Cost Printed Circuit Board (PCB) Technology (EPC-16-035)	GFO-16-032: Scaling Reliable, Next Generation Perovskite Solar Cell Modules
Cost-effective Large-Scale Manufacturing of Emerging PVs	No projects	GFO-16-302: Scaling Reliable, Next-Generation Perovskite Solar Cell Modules
High Value Applications for Thin Film PV	No projects	No projects
In-situ Upgrade Methods and Strategies for Thin-film PV	No projects	No projects

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

The Energy Commission's initiatives will leverage breakthroughs in materials science applicable to emerging thin-film PV technologies to advance the thin-film PV technologies. The initiatives will provide the applied R&D and technology demonstration needed to move emerging thin-film PV technologies to market and large-scale commercialization. Using exclusive features of flexible thin-film PVs to identify innovative high value applications will be another key part of a holistic research approach.

Initiative 4.1.1 Advance the Material Science, Manufacturing Process, and In-Situ Maintenance of Thin-film PV Technologies

Description

This initiative will advance the material science associated with emerging thin-film PV technologies by exploring the advantages of changes in materials composition substituting toxic and/or rare elements with non-toxic and abundant alternatives. This initiative will develop novel encapsulating materials and techniques that will prevent module failures and pave the pathway for large-scale application.

Recent R&D efforts have demonstrated that some thin-film PV materials have efficiencies above 20 percent, but there are toxicity and stability issues. Efforts to replace toxic rare elements and/or optimize materials composition have proven

	that cheap, environmentally-friendly thin-film PV modules with acceptable degradation rates can be developed. Their efficiency must be improved to make these technologies competitive. As thin-film PV technology matures, the need for large scale manufacturing will arise. If new custom equipment is needed for all parts of the supply chain, the market will be disincentivized to invest in this technology. If existing manufacturing equipment and processes can be used to manufacture thin-film PV, the capital costs associated with mass manufacturing will be lower. Emerging thin-film PV technologies possess numerous unique qualities such as flexibility, ability to take different shapes, wide range of possible transparencies and colors, and low weight and provide a variety of interesting possibilities in product integrated applications (for example, integration into buildings, electronic devices, vehicles). The lifetimes of solar flexible modules are considerably shorter than targeted lifetimes of the targeted product carriers. Full integration into buildings and consumer goods would require developing cost-effective in-situ refurbishment and upgrade processes where degraded materials can be flushed out and refilled with fresh PV materials.
Impact if Successful	Combining advancements in materials science of thin-film photovoltaic materials, demonstration of high efficiencies, utilization of abundant and non-toxic materials with effective low-cost encapsulating strategies to increase module life time could lead to a greater acceptance and large-scale adoption of thin film PVs. New market niches that are not feasible for traditional silicon PVs could become available for a lower cost, non-toxic thin film PV technology. In-situ refurbishment would allow integration of thin-film PV technologies in products that require a lifetime currently exceeding the lifetime expectations of any PV technologies.
Primary Users and/or Beneficiaries	PV manufacturer, building developers, car owners, consumer electronics users
Metrics and/or Performance Indicators	Lower costs, greater reliability, increased safety, GHG emissions mitigation and adaptation. Production costs, TRL maintenance costs, life cycle length, raw material savings, job creation
Topic(s) addressed	Thin-film material alternatives Encapsulating materials/techniques Manufacturing Processes for Thin Film PV In Situ/Upgrade Processes

Value Chain Generation
Demand-side Management

Program Area(s) Applied Research and Development
Market Facilitation

Table 33: Ratepayer Benefits Summary For Sub-Theme 4.1

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transpo rtation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 4.1.1 Advance the Material Science, Manufacturing Process, and In-Situ Maintenance of Thin-film PV Technologies		X			X			X	X

Source: California Energy Commission

4.2 Develop Technologies that Enable Increased Wind Capacity in California

On average, wind energy has represented 6 percent of California in-state electricity generation for the last four years, and wind turbines constitute around 25 percent of in-state renewable energy operating capacity.[118] Continued advancement of wind turbine technology offers opportunities to increase the wind energy share and introduce offshore wind energy to the California electricity mix. However, technological challenges remain for high and low land-based wind speed sites and the offshore wind sector.

Land-based wind energy from regions with strong, abundant and consistent wind has been explored since the early 1980s in California, but the potential of wind energy generation has not been fully exploited. That is because a significant percentage of prime wind resource areas are still operating on older, less efficient wind turbine technologies originally installed at the wind power facility. Although less efficient, these turbines continue to function well, raising the bar for cost-effective re-development with more efficient wind turbines. There are also military height and land-use restrictions limiting sites for new wind projects. Based on California Wind Energy Association estimations, due to local and federal land-use restrictions, California is unlikely to see new in-state wind development of more than 2 GW in the 2030 timeframe. Of this, no more than 1 GW would come from the Desert Renewable Energy Conservation Plan (DRECP) area.[119]

Modern land-based wind technology continues increasing turbine nameplate capacity, hub height, and rotor diameter to enhance cost-effectiveness, performance and reliability of system components. Larger wind technology reaches greater winds, achieving higher capacity factor, and enabling wind to be deployed outside developed wind resource areas such as Tehachapi, Solano, Alameda, San Gorgonio Pass, into areas where wind speeds tend to be lower.

Because of continued technical advances in the U.S., land-based wind turbine prices and installed costs have decreased over time, while wind project capacity factors have gradually increased, averaging 33 percent in recent years.[120] In contrast, California wind park performance averaged 25 percent in 2014 and 23 percent in 2015.

Increasing California wind plant capacity factors through technology innovation for high and low speed sites is critical to make wind energy more cost-competitive in the California energy market. Between 2013 and 2014, California added a total of 530 MW on-line capacity of wind energy. The installed units were 3 MW scale turbines for utility-scale projects in Tehachapi and 1-1.5 MW turbines for distributed wind energy generation.[121]

Energy Commission funding for wind technology R&D has focused on land-based wind resources. However, in 2016, Governor Edmund G. Brown Jr requested formation of the California Intergovernmental Renewable Energy Task Force to plan for future renewable wind and wave energy

118 http://www.energy.ca.gov/renewables/tracking_progress/documents/renewable.pdf
119 http://www.energy.ca.gov/research/notices/2016-01-28_wind_workshop/presentations/

120 Department of Energy. 2016. 2015 Wind Technologies Market Report, August 2016.
121 http://www.energy.ca.gov/almanac/

development opportunities in federal offshore waters along the California coast.

NREL has identified a technical resource capacity of 159 GW of offshore wind for California.[122] The potential occurs in deep water, where floating platform technology is needed to support wind turbines. Preliminary findings suggest this offshore wind resource correlates with hourly and seasonal demand and complements solar. A preliminary study found that capacity factors would be high, ranging from 53 to 57 percent over a three-year period.

NREL indicates floating platform technologies provide added benefits because they can be sited farther from shore, which means better wind resources and may mean fewer siting conflicts relative to fixed-bottom technologies. However, because few systems have been deployed, floating wind energy technologies have not benefited from economies of scale to help lower costs. The prototypes that have been deployed have not been optimized. In the future, there is potential for cost parity because floating wind energy technologies can reduce marine operation costs and avoid the need for fixed platforms.[123] Also, further research is needed to assess offshore wind energy facilities' environmental impacts.

Under the first and second EPIC Investment Plans, the EPIC program concentrated on the challenge of repowering wind energy. In addition, the University of California, Davis, and the Energy Commission hosted a two-day symposium in 2013 to explore the future of offshore wind power off the coast of California. The California Offshore Wind Power Forum explored the regulatory, environmental, technical, and economic challenges and opportunities.[124]

KEY TECHNICAL AND MARKET CHALLENGES

Advanced manufacturing and installation approach for utility-scale land-based wind components

The increase in size of modern wind turbines has produced a need for developing advanced manufacturing techniques of blades and drivetrain components to increase reliability, improve efficiency, and reduce manufacturing and operation and maintenance (O&M) costs. The installed capital costs of the drivetrain and rotor blades are 39 percent and 15 percent of the total costs for land-based, utility-scale wind turbines, respectively.[125] The top four turbine components with high failure-caused downtime are gearbox, generator, electronic systems, and rotor blades. In addition to advanced manufacturing techniques for turbine components, there are research opportunities to explore stronger composite materials for the greater durability and strength of blades in varying wind conditions.[126]

High-altitude wind turbines also face high costs and difficult logistics related to steel towers, which range from 100 to 160 meters.[127] Today, the cost of a wind turbine tower represents about 16 percent of the

122 http://docketpublic.energy.ca.gov/PublicDocuments/16-IEPR-03/TN211749_20160608T080633_Offshore_Wind_Energy_Briefing.pdf.

123 Walt Musial. 2016. *Offshore Wind Energy Briefing.* Presentation at the IEPR workshop, May 25, 2016. http://docketpublic.energy.ca.gov/PublicDocuments/16-IEPR-03/TN211749_20160608T080633_Offshore_Wind_Energy_Briefing.pdf.

124 UC Davis California Renewable Energy Center. 2016. Renewable Energy Resource, Technology, and Economic Assessments. California Energy Commission. Publication Number: CEC-500-2017-007.

125 Department of Energy. 2015. Enabling Wind Power Nationwide, May 2015.

126 Ibid.

127 http://www.energy.ca.gov/research/notices/2016-01-28_wind_workshop/presentations/

installed capital cost; and the cost increases rapidly with height, creating a trade-off between tower cost and the value of added energy production.[128] There are significant opportunities for innovation in advanced manufacturing techniques for taller towers, such as development of modular assembly, transformation of the tower production into an on-site industrial process, and promotion of on-site concrete towers or hybrid steel-concrete towers.[129,130]

Real time remote monitoring for offshore and land-based wind technologies

There is a need to establish cost-effective and proactive maintenance based on real-time wireless remote monitoring and control systems to extend wind turbine lifetime and increase productivity.[131] NREL concluded that research on improved use of Supervisory Control and Data Acquisition (SCADA) data and determination of cost-effectiveness monitoring strategy are strategic R&D areas for the sector.[132] The design and implementation of low-cost and robust sensors located in the different components of a wind turbine can be useful in both offshore and land-based wind parks.[133] The improvement in O&M practices by considering performance monitoring for operation and introducing condition-based maintenance has an O&M cost reduction opportunity of 21 percent for offshores plants and 11 percent for land-based plants.[134]

Table 34: Previous and Planned EPIC Investments on Wind Technology

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Aging wind turbines	No projects	EPC-16-019: 21st Century Solutions for 20th Century Wind Projects (GFO-16-301)
High elevation wind	No projects	No current or planned investments
Real-time monitoring systems for wind	No projects	No current or planned investments

Source: California Energy Commission

128 U.S. Department of Energy. 2015. Wind Vision: A New Era for Wind Power in the United States. (https://energy.gov/sites/prod/files/2016/04/f30/wind_vision_highlights.pdf)
129 https://www.energy.gov/sites/prod/files/2015
130 Department of Energy. 2015. Enabling Wind Power Nationwide, May 2015.
131 Chakkor, S; Baghouri, M; Hajraoui, A. 2014. Wind Turbines Fault Detection System in Real Time Remote Monitoring. International Journal of Electrical and Computer Engineering. ISNN: 2088-8708.

132 http://www.nrel.gov/docs/fy13osti/58774.pdf
133 Chakkor, S; Baghouri, M; Hajraoui, A. 2014. Wind Turbines Fault Detection System in real Time Remote Monitoring. International Journal of Electrical and Computer Engineering. ISNN: 2088-8708.
134 http://www.nrel.gov/docs/fy13osti/58774.pdf

2018-2020 FUNDING INITIATIVES

The Energy Commission's initiatives will focus on areas not included in previous investments to help achieve California's energy and GHG reduction goals. There are two research areas on this topic: 1) develop an advanced manufacturing and installation approach for utility-scaled land-based wind components; and 2) develop a real-time remote monitoring and control system for offshore and land-based wind technologies. The initiatives may solicit proposals for applied research to investigate emerging issues and advance understanding of environmental impacts of offshore wind. The initiatives may also solicit proposals for technology development and demonstration to advance the manufacturing and installation process of land-based wind technology and advance performance of proactive condition monitoring technologies for both onshore and offshore wind energy facilities.

Initiative 4.2.1 Advanced Manufacturing and Installation Approach for Utility-Scale Land-Based Wind Turbine Components

Description	This initiative will fund projects to support advanced manufacturing techniques of wind turbines components and introduce new composite material for wind towers and blades. Taller tower and larger turbine blades present new challenges to the wind industry because larger turbine blades, capable of harnessing more wind energy, increase rotor costs and structural loads on the nacelle, rotor, and tower. Also, the drivetrains must be able to endure greater loads. This initiative could lead to new manufacturing processes for blade shells and wind towers, new design and test innovative drivetrain concepts for more reliable components, and stronger materials for turbine blades and towers. The projects are aimed at improving the performance of wind technology for high and low speed wind sites, while lowering the LCOE of wind energy in California. The DOE Wind Program is concentrating efforts on improved performance, lower costs, and reduced market barriers of wind power. This initiative will leverage DOE's efforts applied to advanced manufacturing techniques to wind turbine components.
Impact if Successful	This initiative could help California achieve its energy and GHG reduction goals by improving the performance of wind technology and exploring untapped areas with lower wind speeds. Advancing manufacturing techniques for larger wind technologies, create opportunities for further LCOE reductions and increase the share of wind energy in the electricity mix.
Primary Users and/or Beneficiaries	The primary direct beneficiaries of the research findings would be land-based wind technology developers and operators. The advanced manufacturing techniques in wind turbine

	components and the introduction of stronger composite material for wind turbine blades and towers will also benefit ratepayers by adding more cost-competitive clean energy to California's electricity mix, providing local jobs and helping California remain a leader and pioneer in wind energy.
Metrics and/or Performance Indicators	LCOE of Land-Based Wind Capacity Factor Downtime due to failures (days)
Topic(s) addressed	Advanced manufacturing techniques of blade shell Advanced building process of wind towers Advanced manufacturing techniques for more reliable drivetrain components Use of stronger materials in wind blades Cost-effective techniques to build concrete or hybrid concrete/steel wind towers for high altitude wind
Value Chain	Generation
Program Area(s)	Applied Research and Development Technology Development and Demonstration

Initiative 4.2.2 Real-Time Remote Monitoring System for Offshore and Land-Based Wind Technologies

Description	This initiative will fund projects to support the development and deployment of a cost-effective real time remote monitoring and control system for off-shore and land-based wind turbines. Monitoring and diagnosis is essential to reduce maintenance costs and ensure wind power generation. The projects that will be funded will reduce the maintenance costs by introducing a proactive maintenance system (preventive approach) that avoids unexpected failures that lead to expensive repair, generation loss, and minimizes downtime and maximizes technology performance. This initiative will help reduce the costs of a robust sensor network for wind energy parks.
Impact if Successful	This initiative will help California achieve its energy and GHG reduction goals by improving the ability to monitor performance of wind energy facilities. Performance monitoring for operation and condition-based maintenance has the potential to reduce O&M costs by more

	than 20 percent for offshore turbines and more than 10 percent for land-based turbines.
Primary Users and/or Beneficiaries	Offshore and land-based wind operators will benefit from the research. Having a proactive maintenance system will benefit ratepayers by adding more cost-competitive and reliable clean energy to the electricity mix. This will create local jobs and help California remain a leader and pioneer in wind energy.
Metrics and Performance Indicators	O&M costs for offshore and land-based wind energy**,** LCOE of offshore wind, LCOE of land-based wind, and downtime due to failures (days)
Topic(s) addressed	Real-time monitoring and control systems for off-shore and land-based wind turbines Low-cost sensor network for different wind turbine components Improve SCADA data quality
Value Chain	Generation
Program Area(s)	Applied Research and Development Technology Development and Demonstration

Table 35: Ratepayer Benefits Summary For Sub-Theme 4.2

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 4.2.1 Advanced Manufacturing and Installation Approach for Utility-Scale Land-Based Wind Turbine Components		X			X			X	X
Initiative 4.2.2 Real-Time Remote Monitoring System for Offshore and Land-Based Wind Technologies		X						X	X

Source: California Energy Commission

4.3 Increase the Strategic Value of CSP and Geothermal to the Electricity System

California is a climate leader and has an aggressive RPS goal, targeting 50 percent of retail electricity to come from renewable sources by 2030. Concentrating Solar Power (CSP) with thermal energy storage (TES) and geothermal power generation systems can provide the renewable resources needed, but also flexible generation needed to match the high penetration of intermittent renewables into the grid. CSP with thermal storage can be developed as a baseload, intermediate or peaking power resource. It has the flexible and peaking power capability to provide the greatest value.

CSP captures and stores the sun's energy in the form of heat, then transfers the heat to a working fluid that drives a conventional power generation such as steam turbine. PV, in contrast, converts the energy from the sun directly into electricity. Integrating TES allows the CSP system to operate at night or beyond "sunny hours." Such flexibility becomes increasingly important as more variable renewable generation is added to the system. According to one DOE analysis, under a 40 percent RPS in California, CSP with storage could provide more than twice as much value to the electricity system as variable-generation PV.[135]

The major barrier to CSP deployment is cost-effectiveness or costs associated with acquiring, installing and maintaining CSP-TES. Ten years ago, CSP was more cost-effective than PV. The cost of PV dropped drastically because of the massive investment and deployment of PV. That did not happen with CSP. Given a cost-effective system, CSP with TES can have advantages over other energy storage technology such as battery storage where the cost and lifetime of batteries remains uncertain, are limited in their ability to shift large amounts of energy, and performance decreases over time.

"CSP CLEARLY HAS VALUE AS A FLEXIBLE RENEWABLE ENERGY SOURCE THAT PROVIDES GRID STABILITY AND FLEXIBLE GENERATION, BUT THERE ARE COMPETING STORAGE TECHNOLOGIES THAT MAKE ADVANCEMENT IMPERATIVE FOR HIGHER-EFFICIENCY AND LOWER-COST CSP."

DEPARTMENT OF ENERGY, CONCENTRATING SOLAR POWER GEN3 DEMONSTRATION ROADMAP[136]

There are some successful commercial deployments in the country, mainly CSP systems using two-tank sensible storage system with molten salt as the storage medium. New CSP in the US now totals 1,312 MW, with 922 MW (or about 70 percent) of this installed capacity coming from the three CSP facilities in California (Ivanpah, Genesis, and Mojave).[137] There were other plans or proposals to install additional CSP in California, but most of them have either converted to PV or cancelled plans because of issues such as economics.

To address the economic and technical barriers to CSP, the DOE's SunShot portfolio is developing CSP systems operating at high

135 DOE SunShot. "On the path to SunShot: Executive Summary." https://energy.gov/sites/prod/files/2016/05/f31/OTPSS%20-%20Executive%20Summary-508.pdf

136 http://www.estelasolar.org/Docs/Publications/Others/NREL_2017_gen3_roadmap.pdf

137 https://energy.gov/sites/prod/files/2017/02/f34/Gen3%20Workshop_SunShot%20Overview_Shultz.pdf

temperature for increased efficiency and lower cost. In its study, the SunShot program recommended a supercritical carbon dioxide (sCO_2) turbine cycle for the power generation component because of its ability to exceed 50 percent net cycle efficiency at smaller capacities as low as 10 or 20 MWe. DOE's research is investigating three technological pathways based on the phases of matter of the materials (liquid, solid and gaseous) to achieve the target high temperature for highly efficient operation.[138]

Under *EPIC 2012 – 2014 Investment Plan*, the Energy Commission funded a research project on low-cost thermal energy storage for dispatchable CSP (EPC-14-003 with UCLA). This project is developing and demonstrating elemental sulfur as a robust and low-cost thermal energy storage fluid that will enable overall low system costs, long lifetime, and scalability for a wide range of CSP applications and temperature. Another project was going to investigate systems integration of containerized molten salt thermal energy storage in a novel cascade layout (EPC-14-004 with Halotechnics). Preliminary designs and analysis were done but were not pursued because of a lack of commercial traction. Both research projects with UCLA and Halotechnics also received funding support from the DOE.

"GEOTHERMAL POWER HELPS LOAD SERVING ENTITIES AVOID ADDITIONAL COSTS FROM PURCHASING AND THEN BALANCING INTERMITTENT RESOURCES WITH STORAGE OR OTHER BACKUP SOURCES OF POWER."
GEOTHERMAL ENERGY ASSOCIATION[139]

Geothermal energy also has a potential to operate flexibly and support grid reliability. Geothermal energy is an abundant and valuable resource in California. It provides many benefits to the grid that intermittent power sources cannot. Geothermal power has been considered as a baseload resource, but advancements in technology make it possible for it to provide ancillary and on-demand services, such as load-following, spinning reserves, non-spinning reserves, and replacement or supplemental reserves. Geothermal power helps load-serving entities avoid additional costs from buying and balancing intermittent resources with storage or other backup sources of power.[140] These additional costs are generally not included when comparing the costs of intermittent power technologies to other power technologies. Although geothermal has a relatively low LCOE, it has high start-up capital costs.[141] Research is needed to help lower these costs.

New advancements in geothermal exploration and characterization technologies have been in development with support of programs like the Geothermal Grants and Loan Program also known as

138 http://www.nrel.gov/docs/fy17osti/67464.pdf

139 http://www.geo-energy.org/pressReleases/2017/Geothermal_is_Good_for_America.aspx

140 U.S. Geothermal Electric Power Sector: Good for America's Energy System and Economy, http://www.geo-energy.org/reports/2017/GEOTHERMAL%20IS%20GOOD%20FOR%20AMERICA.pdf

141 Lazard's Levelized Cost of Energy Analysis—Version 10.0, Dec. 2016, https://www.lazard.com/media/438038/levelized-cost-of-energy-v100.pdf

GRDA (Geothermal Resources Development Account where the grants and loan program's funding is coming from). Projects include new analytical methods to predict what regions hold the greatest geothermal potential, and new sensors to characterize the subsurface.

A research project funded under the *EPIC 2012 – 2014 Investment Plan* is investigating the flexible generation capabilities at the Geysers (EPC-14-002 with Geysers Power, LLC). Under the *EPIC 2015 – 2017 Investment Plan*, a project was funded to investigate the issues of flexible geothermal operation through physical-chemical modeling aimed at reducing risks and costs of flexible geothermal energy production (EPC-16-022 with LBNL).

One technology that has received a lot of research and development attention is mineral recovery. This technology has the potential to add new revenue stream, making geothermal power more cost-effective and more attractive to investors. A cost effective mineral recovery process needs to be developed and commercialized in order to make this a reality. While several companies have come close, none have been successful at commercializing such a process.

KEY TECHNICAL AND MARKET CHALLENGES

There have been significant technological advancements in CSP and geothermal but there are challenges to making them cost-effective, particularly for CSP, and for them to provide the flexibility and other grid services. For CSP and new geothermal technologies to reach their potential, the following barriers need to be addressed:

Efficient and low cost thermal energy storage and heat transfer fluid for CSP

Thermal energy storage allow CSP plants to generate during off-peak periods or in the evening, reducing peak demands and system variability, and provide high value ancillary services. NREL estimated that integrating TES allows CSP to achieve annual capacity factors of up to 70 percent or more. TES adds significant costs and additional footprint (oversize solar field) to the CSP system. Several research projects funded by DOE investigated a range of issues on this topic. Examples include the use of molten salt carbon nanotubes, liquid CO_2 as heat transfer fluid, use of solid ceramics for the energy storage vessels, and liquid metals as potential heat transfer fluids. In addition to the two Energy Commission-funded thermal energy storage projects with UCLA and Halotechnics, the Energy Commission also funded a project through the Public Interest Energy Research Program (PIER). The project looked at the thermodynamic modeling of different solar generation-thermal energy storage configurations to evaluate the economic potential and examine the relative performance of a variety of TES technologies.

Low cost and improved receivers and absorbers

According to DOE's Sunshot Initiative, mirrors represent 40 percent of the total system costs for CSP plants, while receivers represent another 15 percent. Some technical challenges that are, or need to be, addressed include: improving solar transmissivity of mirrors; developing lighter-weight reflective surfaces; developing reflector coating to reduce maintenance; improving reflectivity assessments to improve maintenance; efficient detection of microdefect and accelerated aging; and increasing efficiency of absorbers to operate at higher temperatures. Research at Sandia National Laboratories in collaboration with NREL is looking at the high-temperature solar-selective coatings to meet high-performance needs for power tower receiver. NREL is researching how to improve the thermal and optical efficiency of receiver tubes and the optical efficiency of parabolic trough reflector modules.

Component integration and system requirements for flexible operation for CSP

There are challenges toward full integration and operation, and realization of the benefits that CSP can provide to the grid. Among them include mitigating operational issues such as the impact of corrosion on pipes due to molten salt, optimizing power system and heat exchangers, start up and shut down issues, and control systems needed to operate the system flexibly. A more holistic study is needed to determine overall impacts, for example, on land, water, solar flux issues, other environment parameters, the whole electricity system, system economics, and comparative advantage over conventional energy storage systems. Because CSP requires large area of intensely sunny land, impacts include the habitat of animals, solar flux killing birds and bats, and water use, which can be significant depending on choice of cooling system (DOE's third-generation plans for CSP is geared towards dry cooling).

Low cost alternatives to conventional CSP

Conventional CSP projects are typically large, on the scale of over 10 MWe, require a large area and use expensive and extensive materials and infrastructure. There are promising efforts at developing smaller scale, relatively simpler and lower cost using alternative materials, manufacturing, and installation approaches for CSP systems. One example is Hyperlight Energy's CSP collector system which was funded under an earlier research project and subsequently received follow on funding from the DOE and Energy Commission (EPC-16-016 federal cost share and EPC-14-047 as a subcontractor). Hyperlight's technology is based on the Linear Fresnel Reflector (LFR), which uses long flat mirrors to reflect sunlight to a receiver. It claims to achieve dramatic cost reductions through breakthroughs in materials, design, manufacturing and installation. Innovations such as this and others based on LFR and parabolic trough suffer from the lack of economy of scale without breakthrough reductions in system costs. There is a need to demonstrate and deploy these emerging systems beyond bench scale to generate information needed to be cost-effective.

Flexible geothermal energy generation

New technologies have allowed some geothermal resources to operate flexibly. But major barriers, mainly cost, still exist that prevent the widespread implementation of flexible geothermal energy production. Geothermal power plant operating costs are mostly fixed costs. Lowering the power generation does not lower operating costs, and can increase maintenance costs due to added stresses on the infrastructure. Power purchase agreements do not currently compensate geothermal producers adequately to cover the costs and lost revenue from flexible operation. New technologies or strategies are needed to overcome this barrier to help flexible geothermal power generation be cost-effective. This might include innovative, low-cost heat storage technologies or new cost structuring concepts that require intermittent power producers to pay for the flexibility.

Exploration, resource characterization and resource development

A major barrier to new geothermal power plants is the risk and associated costs of discovering and characterizing a resource. Drilling and constructing wells is the most expensive activity in geothermal power plant development. New tools that will help geothermal developers know where to drill with greater confidence will decrease the risk and expense of geothermal exploration and resource characterization.

Increasing cost effectiveness and economic opportunities of geothermal power generation

If a geothermal plant can offset its large capital costs faster, then it will be more attractive to investors. This can be done in a number of ways. New materials or components that increase the efficiency of the power plant or lower maintenance costs will increase cost effectiveness. Additional revenue streams such as mineral recovery will make geothermal power plants more attractive to investors. Many resources have limited generation potential due to the fact that fluid or permeability is not sufficiently present. New tools or strategies to increase generation from these less ideal resources will help geothermal power plants to be more cost effective and will open up more opportunities for new geothermal power. To help facilitate the successful deployment of newly developed technologies, demonstrations are needed to illustrate how they are cost-effective in real world applications.

Table 36: Previous and Planned EPIC Investments on Concentrating Solar Power and Geothermal

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Efficient and Low Cost Thermal Energy Storage and Heat Transfer Fluid	Low- Cost Thermal Energy Storage for Dispatchable CSP (EPC-14-003) Systems Integration of Containerized Molten Salt Thermal Energy Storage in Novel Cascade Layout (EPC-14-004)	No current or planned investments
Low Cost and Improved Receivers and Absorbers	No projects	No current or planned investments
Component Integration and System Requirements for Flexible Operation	No projects	No current or planned investments
Low Cost Alternatives to Conventional CSP	Dairy Waste-to-Bioenergy via the Integration of Concentrating Solar Power and a High Temperature Conversion Process (EPC-14-047)	Commercializing a Disruptively Low Cost Solar Collector (EPC-16-016)
Flexible Geothermal Energy Generation	Investigating Flexible Generation Capabilities at the Geysers (EPC-14-002)	Comprehensive Physical-Chemical Modeling to Reduce Risks and Costs of Flexible Geothermal Energy Production (EPC-16-022)
Exploration, Resource Characterization and Resource Development	No projects	High-Resolution Imaging of Geothermal Flow Paths Using a Cost Effective Dense Seismic Network (EPC-16-021)
Increasing Cost Effectiveness and Economic Opportunities of Geothermal Power Generation	No projects	Recovery of Lithium from Geothermal Brines (EPC-16-020)

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

The funding initiatives will lower the cost, improve the efficiency, and advance the potential for the flexible operation of CSP and geothermal in support of high penetration of renewable energy. Increasing cost effectiveness and demonstrating the benefits of emerging CSP and geothermal developers and investors will help progress these technologies into industry.

Initiative 4.3.1 Making Flexible-Peaking Concentrating Solar Power with Thermal Energy Storage Cost Competitive

Description	This initiative will conduct comprehensive research, technology development and demonstration, and studies that will advance the technology readiness of CSP-TES, bring it closer to the market, and make CSP-TES cost competitive compared to fossil fueled power generation and conventional (battery) energy storage system. In order to achieve the goal, the initiative will support comprehensive technical and economic comparison of CSP-TES to other renewable generation, such as other solar, with battery energy storage. Part of this comprehensive study will include holistic simulation and modeling to yield information on the economic implications of emerging and alternative designs; needs and economics of operating CSP as a peaker power plant; and identifying deployment areas and potential environmental and permitting impacts. Technological development is also needed to further achieve a more efficient and cost competitive CSP-TES system. This initiative will also leverage CSP technology developments considered under earlier EPIC program investment plans while complementing the DOE SunShot program on CSP by conducting research, development and demonstration on emerging and alternative designs for specific critical components – namely thermal energy storage, working fluids, reflectors and receivers – for particular CSP configurations (for example, power tower, linear Fresnel or parabolic trough) at a scale that will yield improved cost-competitiveness. The cost-competitive scale is anticipated to be at least 10 MW (for example, based on installed systems and DOE SunShot program Gen3 study), however this initiative will not put a minimum cap on the scale of the system.
Impact if Successful	More cost effective and financially viable CSP with thermal energy storage will attract investors and increase likelihood of deployment which will make significant contribution to the RPS goal, provide flexible generation needed to support

	variable renewables, and generate economic and job creation opportunities.
Primary Users and/or Beneficiaries	CSP developers and investors, electric utilities and balancing authorities, and ratepayers or everyone who buys electricity
Metrics and Performance Indicators	Capital and O&M costs, components and system costs including cost of output electricity, high temperature ability, system efficiency, quality of designs, operational requirements, impacts and implications. Example indicators are DOE SunShot goals of: • \$0.06/kWh • <\$15/kWh for thermal energy storage • System temperature of over 700 ˚ C and power cycle efficiency of at least 50 percent.
Topic(s) addressed	Efficient and low-cost thermal energy storage and heat transfer fluid Low cost and improved receivers and absorbers Component integration and system requirements for flexible operation Low-cost alternatives to conventional CSP
Value Chain	Generation
Program Area(s)	Applied Research and Development

Initiative 4.3.2 Geothermal Energy Advancement for a Reliable Renewable Electricity System

Description	Based on project findings and discussions with facility owners, operators prefer to operate geothermal as a baseload because of issues associated with flexible generation, such as the buildup of hydrochloric acid, hydrogen sulfide and other corrosive and toxic materials. From an efficiency perspective, steam generation and the energy associated with distribution are generally wasted or lost during curtailment of production. This initiative will address flexible generation issues identified by exploring strategies such developing materials, designs and operational techniques to mitigate corrosion issues and possibly integrating energy storage, a strategy that has not yet been demonstrated. The initiative will also support activities that explore the economic values of capturing the useful elements from buildup of these condensates (such as solid sulfur for agriculture use or metals for industrial application).

	The initiative will also support strategies that boost geothermal from existing facilities and wells that are declining or idle. The goal is to further position geothermal energy as a key player in attaining the RPS goal by backing up intermittent renewables and providing sustained and increased renewable generation to the grid.
Impact if Successful	Accelerated penetration of renewables in the electricity grid and reducing the need for non-renewable generation systems that can ramp up and down to support variable renewables. It could lead to more cost effective geothermal power plants, making them more attractive to investors.
Primary Users and/or Beneficiaries	Geothermal developers, utilities
Metrics and Performance Indicators	Rates or ability to ramp up and down, lower costs, additional revenue
Topic(s) addressed	Flexible geothermal energy generation; increasing cost effectiveness and economic opportunities of geothermal power generation
Value Chain	Generation
Program Area(s)	Applied Research and Development

Table 37: Ratepayer Benefits Summary For Sub-Theme 4.3

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 4.3.1 Making Flexible-Peaking Concentrating Solar Power with Thermal Energy Storage Cost Competitive	X	X			X			X	X
Initiative 4.3.2 Geothermal Energy Advancement for a Reliable Renewable Electricity System	X	X			X			X	X

Source: California Energy Commission

4.4 Improve the Value Proposition of Bioenergy

In 2015, SB 350 was approved with a goal to increase procurement of renewable electricity to 50 percent by 2030.[142] The CPUC biomass feed-in-tariff program will help achieve this goal.[143]

According to the Energy Commission's 2016 Tracking Progress Report for renewable energy, biomass was 12 percent of the renewable generation mix.[144] In terms of estimated capacity (the maximum electric output a generator can produce under specific conditions), in-state biomass was only 5 percent of the renewable mix. Bioenergy converts waste into a resource, allowing for the dual benefit of waste management and renewable energy production. The number of biomass plants has decreased significantly since the 1980s as long-term contracts expire, leaving limited options to convert orchard and agricultural waste to energy.[145]

"IN 2016 ALONE, 62 MILLION TREES DIED, REPRESENTING MORE THAN A 100 PERCENT INCREASE IN DEAD TREES ACROSS THE STATE FROM 2015."

US FOREST SERVICE[146]

In November 2016, the U.S. Forest Service estimated there were more than 102 million dead trees on 7.7 million acres of California's drought-stricken forests. Millions of additional trees are weakened and expected to die in the coming months and years, increasing the potential risk of catastrophic wildfires.[147,148] Bioenergy is critical in the portfolio of options to address issues caused by the enormous number of dead trees.

Bioenergy projects offer renewable baseload generation, but also have the potential to provide grid services, such as flexible generation and energy storage. Increasing the flexibility of bioenergy generation could improve the marketability and help address the "duck curve" associated with solar and wind generation.[149]

In spite of known value to the grid, to the environment (including forest, agriculture, and urban organic wastes) and society, the costs of bioenergy systems remain a major barrier. For a new 50 MW biomass power plant, an Energy Commission report projected the LCOE at an average range of $147/MWh up to $240/MWh with instant cost of $3,143/kW to $5,060/kW.[150] Capital costs for small-scale biomass power plants have can be high: $7,000/KW to $8,000/kW. "Historically, biomass facilities have required 12 – 13 cents per kilowatt hour to

142 https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350

143 http://cpuc.ca.gov/SB_1122/

144 Determined by the amount of RPS-eligible generation divided by (electric utility) retail sales http://www.energy.ca.gov/renewables/tracking_progress/documents/renewable.pdf

145 http://naturalresourcereport.com/2016/08/californias-big-biomass-problem/

146 https://www.fs.fed.us/news/releases/new-aerial-survey-identifies-more-100-million-dead-trees-california

147 https://www.fs.fed.us/news/releases/new-aerial-survey-identifies-more-100-million-dead-trees-california

148 http://cdfdata.fire.ca.gov/incidents/incidents_stats?year=2015

149 https://www.greentechmedia.com/articles/read/10-ways-to-solve-the-renewable-duck-curve

150 http://www.energy.ca.gov/2014publications/CEC-200-2014-003/CEC-200-2014-003-SD.pdf

retain economic viability."[151] Technological development is still needed to achieve LCOE at or below the $120/MWh to maintain economic attractiveness for power purchase contract from utilities.

Improving the value proposition of bioenergy is critical to ensuring it continues to be part of California's renewable energy portfolio and ensure it is available to help rural communities with forest management and wildfire risk reduction. To succeed in the market without public subsidies, technology advancements are needed to improve the LCOE of bioenergy and address air emission concerns.

KEY TECHNICAL AND MARKET CHALLENGES

The most important bioenergy challenge is cost, including the cost of controlling air emissions and, for gasification, the cost of damage caused by tar formation and other impurities. Other factors contributing to bioenergy's high costs include transportation of biomass waste-feedstock, system impact studies, and interconnection.

The costly collection and transport of forestry residue can make a bioenergy project uneconomical. Research into energy densification systems and partial onsite conversion for feedstock transport to biomass generation facilities could help reduce the cost of feedstock transport.

One way to address the cost of feedstock transport is to keep bioenergy projects at a "community-scale," sized to the quantity of sustainable, locally sourced waste-biomass available for power generation. However, advances are needed to improve the performance and reduce operation and maintenance costs of community-scale biomass facilities. If technical and market challenges can be overcome, there may be additional co-benefits to community-scale projects in the urban/rural interface.

For forest biomass, EPIC funding focuses on forestry residue derived from sustainable forest management activities. Funding targets the tree mortality issue in High Hazard Zones (HHZ).[152] The use of HHZ forestry-residue bioenergy feedstock in a controlled, electricity generating system can provide air quality benefits over open pile-burning or catastrophic forest fires.

Advanced Pollution Control Equipment and Low Emission Generators

Strict air quality standards within the San Joaquin and South Coast air districts require the demonstration and deployment of advanced pollution control equipment and low-emission generators that can meet air quality standards at pilot scale. In addition, cost-effective compliance technologies and mitigation measures are needed to commercially deploy bioenergy systems.[153] The U.S. Environmental Protection Agency's (EPA) rule for toxic and hazardous air pollution may be challenging for existing solid-fuel biomass facilities to meet, particularly with hydrogen chloride emissions.[154]

Developing Modular Bioenergy Systems

Modular technologies and strategies for the sustainable collection, transportation,

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151 http://www.capcoa.org/wp-content/uploads/2016/12/CAPCOA_Biomass_Policy_Dec_2016.pdf

152 The link to the HHZ map is: http://egis.fire.ca.gov/TreeMortalityViewer/.

153 *Economic Feasibility of Dairy Manure and Co-Digester Facilities in the Central Valley of California.* May 2011. Prepared for the California Regional Water Quality Control Board, Central Valley Region by Environmental Science Associates.

154 California has higher than average chloride concentrations compared to the rest of the US. Reasons include proximity to high concentrations of chloride in the ocean and irrigated regions with high salinity. Chloride that is absorbed by vegetation can be transformed to HCl during combustion.

management, and power generation from forest residue and thinning have the potential to provide renewable electricity while also reducing forest fire risk and providing other benefits to IOU electricity ratepayers.

Modular low-emission technologies and systems for woody biomass management and conversion could help reduce the risk and severity of catastrophic wildfires. It would be useful to develop biomass-to-energy systems that can be economically transported and/or replicated at forest locations throughout California.

EPIC is currently supporting development of a few modular bioenergy systems that can be located near the waste feedstock to reduce transportation costs and associated emissions. Projects funded under this area typically involve direct coordination among the technology developer and provider, bioenergy users, local jurisdictions such as counties or cities, and other permitting agencies to increase the technologies' market readiness. For example, one project is developing a pilot-scale modular biomass gasification system integrated with a high-efficiency lean-burn engine and involves members of the Yuba Watershed and Nevada County Fire Safety councils as Technical Advisory Committee members, increasing community participation Converting forest residue into renewable grid power increase the benefits of forest fuel reduction projects in California's high-risk regions.

Figure 10 California Forests Have Experienced an Unprecedented Die-off

Source: California Energy Commission; Photo by Gina Barkalow

Developing Waste-to-Energy Bioenergy Systems

EPIC is currently supporting applied research for technologies and strategies using the organic fraction of municipal wastes, agricultural residues, and food processing wastes to provide renewable, reliable electricity generation while providing additional benefits. Processing methods, conversion technologies, and operation and maintenance practices to increase efficiency, reduce costs, and improve environmental performance are needed to improve the LCOE of bioenergy systems. Strategies aim to generate electricity and useful thermal energy to achieve cost parity with fossil-fuel power.

Demonstrating Thermochemical Conversion Technologies and Deployment Strategies

Bioenergy projects using thermochemical conversion technologies and generation systems are challenged by high costs associated with capital, interconnection, and demonstration facilities to comply with air emissions requirements. There are also challenges associated with the reliability of downstream gas treatment and catalyst systems caused by siloxanes and other impurities in untreated biogas.[155]

One EPIC project is demonstrating a commercial-scale gasification-to-electricity facility that converts wood waste from forest management activities to renewable electricity while addressing a number of challenges to bioenergy deployment including cost associated with the technology system, interconnection, reliability of operation, and issues with emissions and other waste products. Benefits include reduced fire risk, watershed protection, improved air quality, and local jobs. Furthermore, it will increase rural energy security and provide lessons learned for future projects.

Demonstrating Biochemical Conversion Technologies or Deployment Strategies

Most EPIC-supported biochemical conversion demonstrations deal with dairy waste. EPIC-funded dairy digester projects are taking innovative approaches to bring down the LCOE. One project is demonstrating a "hub-and-spoke" dairy digester cluster approach. The benefits of using biogas from neighboring dairies includes aggregating capital investment and reducing operation and management costs by centrally locating the generators and associated electrical equipment. Another project is demonstrating a system consisting of a double-cell covered lagoon digester and 1 MW electricity generation facility. This system can vary wastewater volumes by time of year to enable co-digestion to increase biogas output. The digester also has biogas storage capacity, which opens up the possibility of providing energy storage.

In 2015, the California Department of Food and Agriculture (CDFA) provided more than $11 million worth of funding through its Dairy Digester Research and Development Program (DDRDP) and anticipates spending an additional $29 to $30 million through its 2017 DDRDP. The EPIC program plans to prioritize research on areas not being funded by CDFA and is not proposing new dairy digester research initiatives.

There is a continued need to demonstrate advanced biochemical conversion systems for organic waste. New bioenergy developments that divert organic materials from landfills can help the state achieve a 75 percent diversion of waste from landfills, reducing GHG emissions significantly through landfill methane avoidance, alternative energy production, and water conservation.[156,157] Waste-based resources can also improve the environmental impacts of bioenergy because they avoid concerns associated with forestry and agricultural feedstocks, such as over-harvesting or purpose-grown crops. CalRecycle receives Greenhouse Gas Reduction Funds for GHG emission reduction programs such as the CalRecycle Organics Grant Program which allocated $24 million for Fiscal Year 2016-2017, including $12 million for digestion projects.[158] These funds support systems that are commercially available, while EPIC

155 O'Neill, Garry, John Nuffer. 2011. *2011 Bioenergy Action Plan.* California Energy Commission, Efficiency and Renewables Division. Publication number: CEC-300-2011-001-CTF.

156 O'Neill, Garry. 2012. *2012 Bioenergy Action Plan.* California Energy Commission, Efficiency and Renewables Division. www.resources.ca.gov/docs/2012_Bioenergy_Action_Plan.pdf

157 O'Neill, Garry. 2012. *2012 Bioenergy Action Plan.* California Energy Commission, Efficiency and Renewables Division. www.resources.ca.gov/docs/2012_Bioenergy_Action_Plan.pdf

158 http://www.calrecycle.ca.gov/Climate/GrantsLoans/Organics/FY201617/default.htm

funding targets pre-commercial technology advancements.

Demonstrating Community-Scale Clean Energy Solutions for California's Industries, the Environment and the Electrical Grid

California's electricity grid is undergoing significant changes as energy efficiency continues to improve and roof-top solar becomes more affordable. These developments are crucial for California to meet its emission reduction goals. The growing number of customer-generators is changing the amount, timing, and ramp-rate of energy required from utilities. New solutions will be required for the future electricity grid to continue providing electricity to customers on demand.

Table 38: Previous and Planned EPIC Investments on Bioenergy

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Advanced Pollution Control Equipment and Low Emission Generators	Pollution Control and Power Generation for Low Quality Renewable Fuel Streams (EPC-14-031)	May qualify under:
Develop Modular Bioenergy Systems for Forest/Urban Interface Areas	Modular Biomass Power Systems to Facilitate Forest Fuel Reduction Treatments (EPC-14-024) Reciprocating Reactor for Low-Cost & Carbon Negative Bioenergy (EPC-14-034) Cleaner Air - Cleaner Energy: Converting Forest Fire Management Waste to On Demand Renewable Energy (EPC-14-051)	The Nexus of Clean Energy, Healthy Forests, and a Stable Climate: Innovative Biomass Gasification for Sustainable Forest Management (TBD) Small Scale Forest Waste Power System (TBD)
Develop Waste-to-Energy Bioenergy Systems	Robust, Low-Cost, Real-Time, NOx Sensor for Optimization of Dispatchable Distributed Generation Systems (EPC-15-062) Advanced Recycling to 1-MW Municipal Solid Waste of Electricity Generation (EPC-14-045) The SoCalGas Waste-to-Bioenergy Applied R&D Project (EPC-14-047) Paths to Sustainable Distributed Generation through 2050: Matching Local Waste Biomass Resources with Grid, Industrial, and Community Needs (EPC-14-030) Low Cost Biogas Power Generation with Increased Efficiency and Lower Emissions (EC-14-028)	No current or planned investments
Thermochemical Conversion Technologies or Deployment Strategies	North Fork Community Power Forest Bioenergy Facility (EPC-14-033)	Biomass-to-Electricity: Pilot-Scale Testing of Baseload Compared to Flexible Power (TBD) An Online Application for Decision Support in Siting Woody Biomass-to-Electricity Facilities in California (TBD) Mariposa Biomass Project (TBD) Camptonville Biomass-to-Energy Project (TBD)
Biochemical Conversion Technologies or Deployment Strategies	The Lakeview Farms Dairy Biogas - To - Electricity Project (EPC-14-022) The West Star North Dairy Biogas-to -Electricity Project (EPC-14-029) Enabling Anaerobic Digestion Deployment for Municipal Solid Waste-to-Energy (EPC-14-044) Lowering Food-Waste Co-digestion Costs through an innovative Combination of a Pre-Sorting Technique and a Strategy for Cake Solids Reduction (EPC-14-046) Community Scale Digester with Advanced Interconnection to the Electrical Grid (EPC-14-052) Installation of a Lean Burn Biogas Engine with Emissions Control to Comply with Rule 1110.2 at a Wastewater Treatment Plant in South Coast Air Quality Management District (EPC-14-041)	Demonstrating the Potential for On-Site Electricity Generation from Food Waste Using Containerized Anaerobic Digestion Units (TBD) Skid Mounted Mobile Pilot/Education Unit for Source Separated Organics Processing with Cogeneration Capabilities (TBD) Kompogas - San Luis Obispo County Food Waste Diversion and Co-products through High-Solids Anaerobic Digestion (TBD)
Demonstrating Clean Energy Solutions that Support California's Industries, the Environment and the Electrical Grid	Advancing Biomass Combined Heat and Power Technology to Support Rural California, the Environment, and the Electrical Grid (EPC-14-082) ABEC #4 Renewable Combined Heat and Power Project (EPC-14-084)	No current or planned investments

Source: California Energy Commission

2018 – 2020 FUNDING INITIATIVES

The funding initiatives for this sub-theme will improve the value proposition of bioenergy to ensure its key role in achieving the State's RPS goal while helping address issues associated with managing biomass waste from forests, including sustainable forestry management strategies to reduce wildfire risk, agriculture, and other sources of organic waste. These initiatives place a larger emphasis on the thermochemical conversion of biomass due to the unprecedented issue of dead and dying trees; the closure of a number of biomass power plants that has impacted not only the forest sector but also the agriculture sector, particularly in the Central Valley where orchard wastes management has become a problem. These initiatives will support more focused research on the barriers to full realization of the potentials of biomass gasification and other conversion strategies that are clean, efficient, and cost-effective and will help address location-challenged biomass resources. Specifically technologies and strategies that reduce the LCOE, and Operation and Maintenance costs and help bring bioenergy into cost parity with fossil fuels. Finally, these initiatives will support low-emission generation technologies, pollution control, and other technologies that can cost-effectively utilize low-quality biogas for bioenergy.

Initiative 4.4.1 Tackling Tar and Other Impurities: Addressing the Achilles Heel of Gasification

Description	Gasification is a promising clean, efficient and potentially lower cost alternative to conventional bioenergy generation. However, gasification has not been successfully deployed in the commercial space due to a number of barriers. Among the barriers is performance reliability due to inconsistent gas quality and the presence of tars and other impurities. This initiative will focus on research that will help to eliminate the reliability risks of gasification technologies due to inconsistent gas quality production and system problems caused by tar and other impurities. Tars, condensable organic molecules (C6 and greater), are a persistent problem in biomass gasification systems. The operating temperatures (typically around 700-900° C) prevent complete cracking of the tar compounds which when condensed, could result in costly damage to the reforming catalysts, as well as the clogging of transfer lines and damaging of compressors, or other downstream devices like engines used for power generation. This problem often results in the need for a more sophisticated and expensive after gasification cleanup. Catalysts are expensive and contribute to the higher cost of thermochemical gasification systems that employ catalysts. Other cleanup strategies that do not use

	catalysts but rather cool down the gas to condense and capture tars are not as effective. Cost-effectively solving the problems caused by tars and other impurities will help make the gasification system more reliable, reduce the risks to downstream equipment, and bring down the costs of thermochemical conversion systems. Research is also needed on safe and environmentally responsible disposal of associated waste (e.g. bed materials or liquids used for condensing and capturing tars) once the tars and impurities have been removed from the product gas stream. The bioenergy initiatives under the previous two EPIC Investment Plans, while partly addressing these issues, were focused on wider and system level thermochemical conversion issues.
Impact if Successful	Could lead to greater adoption of thermochemical conversion technologies, including those using forestry biomass from sustainable forest management activities and targeting the tree mortality issue.
Primary Users and/or Beneficiaries	Ratepayers in rural and urban communities; bioenergy technology developers and investors; communities impacted by the tree mortality crisis looking for community-scale solutions. IOUs dealing with tree mortality in their service territories; local and regional air quality districts; California Air Resources Board; California Department of Forestry and Fire Protection; biomass industry groups; California Department of Resources Recycling and Recovery; Bioenergy Associations of California, independent power producers, and the U.S. Department of Agriculture and U.S. Forest Service
Metrics and/or Performance Indicators	Measured reduction in biogas impurities, such as tar Reduction in costs of demonstrated technology compared to other impurity removal systems Replicable solutions applicable to a variety of thermochemical conversion technologies Capital cost per kilowatt of installed system Levelized cost of electricity ($/kWh)
Topic(s) addressed	Tar and other impurities impacting thermochemical conversion technologies
Value Chain	Generation
Program Area(s)	Applied Research and Development Technology Demonstration and Deployment

Initiative 4.4.2 Demonstrating Modular Bioenergy Systems and Feedstock Densifying and Handling Strategies to Improve Conversion of Accessibility- Challenged Forest Biomass Resources

Description

This initiative will demonstrate modular bioenergy systems in forest/urban interface areas and generate critical field demonstration data needed for broader deployment and commercialization while addressing technological challenges such as integration of multiple units, feeding systems to handle larger volumes of feedstock, interconnection, gaseous fuel quality improvements, emissions and waste management, and opportunities for co-products. The bioenergy systems will demonstrate improvements in conversion efficiency, meet or surpass the strictest state emissions requirements, and will sufficiently reduce and manage solid and liquid waste byproducts so as not to harm the environment, relative to conventional bioenergy conversion methods.

The initiative will also advance methods and strategies needed to more efficiently and cost-effectively bring accessibility-challenged but abundant woody biomass feedstock to power generation facilities. Anticipated projects will demonstrate innovative systems, such as densification and torrefaction, that reduce biomass volume, improve energy density, and could involve partial conversion onsite.

Torrefaction involves mild pyrolysis, or heating at about 200 to 320° C in the absence of oxygen, resulting to coal-like material with better fuel characteristics than the original biomass. Its potential to benefit the bioenergy industry has been demonstrated and the process and product validation has been underway in Europe with some progress. However, the technology needs further demonstration to lower cost, improve performance, and strengthen market readiness specific to California. Torrefaction developers tend to be small companies with a limited financial base and face difficulties in persuading investors to finance the necessary R&D and scale-up efforts. Other biomass collection approaches such as a centralized biomass collection and distribution stations could also help the economics of bioenergy facilities.

Projects may include innovative approaches to providing co-products for improved business opportunities, as long as the primary focus is on electricity generation. Further, interconnection technologies designed to cost-effectively prevent unintentional islanding (the dangerous situation when

	a distributed generation facility continues to power a location even though the electrical grid from the electric utility is no longer present) could help small-scale bioenergy facilities operate safely.
Impact if Successful	Wider adoption of community-scale biomass conversion systems using HHZ feedstock is expected to result in reduced wildfire risk. This initiative is also expected to reduce waste feedstock transportation costs and provide better economics for bioenergy projects.
Primary Users and/or Beneficiaries	Ratepayers in rural and urban communities; bioenergy technology developers and investors; communities impacted by the tree mortality crisis, looking for community-scale solutions. IOUs dealing with tree mortality in their service territories; local and regional air quality districts; California Air Resources Board; California Department of Forestry and Fire Protection; biomass industry groups; California Department of Resources Recycling and Recovery; Bioenergy Associations of California, independent power producers, and the U.S. Department of Agriculture and the U.S. Forest Service.
Metrics and Performance Indicators	Tons of forest biomass from HHZ converted to electricity Megawatts of electricity Capital cost per kilowatt of installed system Levelized cost of electricity ($/kWh) including revenue generated from co-products Power purchase agreements with IOUs Reduction in costs compared with best available emission control technologies. Measured reductions in air pollution compared to conventional emission control technologies.
Topic(s) addressed	Technical and Cost Advancements Modular Bioenergy Systems Flexible Generation Biomass densification, torrefaction, biomass collection, thermochemical conversion technologies
Value Chain	Generation
Program Area(s)	Applied Research and Development Technology Demonstration and Deployment

Initiative 4.4.3 Demonstrate Improved Performance and Reduced Air Pollution Emissions of Biogas or Low Quality Biogas Power Generation Technologies

Description	At small scales, internal combustion engines have been the most reliable generation technology. The equipment needed to control air pollution emissions on these devices can be relatively expensive because cost does not scale down with system size. Other generation technologies, like microturbines and fuel cells, have lower emission profiles but are more costly and can be more complicated to operate. Research is needed to develop and test low-cost pollution controls for small generators and develop simple, but cost effective off-the shelf, low-emission generation technologies. There is also a need for technologies that can use low-quality biogas for bioenergy applications. Many sources of biogas, such as landfills and wastewater treatment plants, produce a "low-quality" gas whose energy content or contaminant levels make them challenging to use with conventional power generation equipment. For example biogas with high levels of hydrogen sulfide, also known as "sour gas," requires substantial pre- and post-combustion cleanup to meet local air quality standards. The capital and operating costs of the required equipment are often cost-prohibitive, stopping many potential projects before they even start. Of the 181 California landfills identified with the potential to convert landfill gas to energy, only 25 are classified as "candidate" landfills that could be implemented cost effectively with today's technology due to scale or production of gas that cannot be used in conventional power generation equipment. There is a need to develop and demonstrate clean, fuel-flexible, and cost-effective technologies for converting low-quality biogas to electricity while meeting local air quality standards. Widespread deployment of these technologies would help California achieve its renewable energy goals, improve air quality, and encourage economic development in the waste management sector.
Impact if Successful	Improved air quality and likelihood of meeting or exceeding future air permitting requirements. Could lead to wider use of biogas that is otherwise emitted or flared
Primary Users and/or Beneficiaries	Ratepayers in rural and urban communities, communities with waste management issues looking for community-scale solutions; IOUs required to procure bioenergy; wastewater

	treatment facilities, and landfills; California Department of Food and Agriculture; local and regional air quality districts; California Air Resources Board; California Department of Food and Agriculture; biomass industry groups; California Department of Resources Recycling and Recovery; waste management industry.
Metrics and Performance Indicators	Reduction in costs compared with best available emission control technologies. Measured reductions in air pollution compared to conventional emission control technologies. Volume reduction in flared gas Volume of low quality biogas converted to electricity MW generated from biogas Use of onsite power or power purchase agreements with IOUs
Topic(s) addressed	Biomass gas collection, low-BTU gas technologies, emission controls, biochemical conversion technologies
Value Chain	Generation
Program Area(s)	Technology Demonstration and Deployment

Table 39: Ratepayer Benefits Summary For Sub-Theme 4.4

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 4.4.1 Tackling Tar and Other Impurities: Addressing the Achilles Heel of Gasification		X		X	X			X	X
Initiative 4.4.2 Demonstrating Modular Bioenergy Systems and Feedstock Densifying and Handling Strategies to Improve Conversion of Accessibility- Challenged Forest Biomass Resources	X	X	X	X	X			X	X
Initiative 4.4.3 Demonstrate Improved Performance and Reduced Air Pollution Emissions of Biogas or Low Quality Biogas Power Generation Technologies		X		X	X			X	X

CHAPTER 6
Theme 5: Create a Statewide Ecosystem for Incubating New Energy Innovations

Transforming California's electricity sector will require innovation at unprecedented levels. The journey from idea to commercial success can be long and full of challenges. "Specific challenges include high capital needs, long development times, the need to integrate into complex systems and supply chains, the need to work with established industry in a commodity market, and the need to operate within a shifting regulatory environment."[159]

"THE CONVENTIONAL TECHNOLOGY-TO-MARKET PATHWAY FROM INVENTION TO MARKET ENTRY HAS PROVEN TO BE CHALLENGING FOR DISRUPTIVE NON-SOFTWARE CLEAN ENERGY TECHNOLOGIES"
DEPARTMENT OF ENERGY, SUPPORTING CLEAN ENERGY STARTUPS[160]

The lack of sufficient capital for new energy inventions has been well documented. While venture capital has been a key source of finance for innovations in other technology sectors, "Evidence shows that the venture capital system is simply not equipped to fund clean energy research and bring viable clean energy solutions to market."[161]

A number of studies and organizations have highlighted the need to reimagine the current model for delivering clean energy technologies to the market. In an op-ed to the Washington Post, MIT President L. Rafael Reif called for "accelerating a two-stage process: from idea to investment, and from investment to impact" that would shorten the full span to meet venture capital's five-year threshold.[162] For this to happen, the innovation ecosystem for energy will need to mature to a stage closer to that of other technology innovation ecosystems such as information technology and pharmaceuticals.

"IT IS CRITICAL…TO BUILD A MORE EFFICIENT AND INTERCONNECTED INNOVATION ECOSYSTEM IN ORDER TO TRANSITION TO A CLEAN ENERGY ECONOMY"
DEPARTMENT OF ENERGY, SUPPORTING CLEAN ENERGY STARTUPS[163]

The funding initiatives described in this chapter seek to leverage, align and expand California's existing assets to build a more efficient statewide energy innovation ecosystem that will:

159 U.S. Department of Energy, *Supporting Clean Energy Start-ups: Industry and Investment Partnerships for Scaling Innovation*
160 https://eere-exchange.energy.gov/FileContent.aspx?FileID=3d063488-c5e2-4850-b30e-c528945be2cc
161 Chazen Benjamin J. *Venture Capital and Research Centers: Facilitating Innovation,* MIT Press, 2016
162 https://www.washingtonpost.com/opinions/a-better-way-to-deliver-innovation-to-the-world/2015/05/22/35023680-fe28-11e4-8b6c-0dcce21e223d_story.html?utm_term=.d9697b92cfd8
163 https://eere-exchange.energy.gov/FileContent.aspx?FileID=3d063488-c5e2-4850-b30e-c528945be2cc

Provide a more systematic approach to move new energy inventions through the "Technological Valley of Death"

The current energy innovation ecosystem lacks an interconnected process to systematically identify, evaluate and progress new energy inventions through the early stages of the technology development pipeline. The Energy Commission seeks to strategically align the various elements and stakeholders of the innovation ecosystems to: provide a continuous path of funding opportunities which can accelerate the pace of new technology development; and expedite the necessary winnowing of new technologies so that limited later-stage resources, including private and public sector funding, can be targeted to technologies with the greatest potential for commercial success.

Reduce non-value added activities and costs from the development of energy technology breakthroughs

Navigating the clean energy innovation ecosystem can be a daunting challenge, especially for entrepreneurs with little experience in the energy sector. Without an entry point into the ecosystem to effectively guide and direct them, entrepreneurs can spend significant time and effort searching for the right support services, mentors and funding opportunities best suited for their invention.

Overcome barriers to broader and more diverse clean energy entrepreneurship

A concerted focus is needed to encourage cultural and geographical diversity in the portfolio of awardees and beneficiaries. To build a more inclusive energy innovation ecosystem, special effort and attention will be needed to overcome barriers that prevent more diverse energy entrepreneurship.

5.1 Close the Innovation Gap from Idea to Investment

Energy entrepreneurs face barriers and challenges particularly in the early development of their technology. These challenges can add unnecessary costs and delays to a new breakthrough technology's development and deter private investment. These challenges include:

Lack of early seed funding to prove concept feasibility

"Venture capitals are unprepared to tackle the longer-term, high-risk earlier research stages, focusing on later stage development, waiting until firms are close to commercialization."[164] This creates a critical funding gap, particularly when entrepreneurs are trying to test out the feasibility of a new concept. Early stage concepts are dependent upon scientific breakthroughs that are difficult to predict and often do not line up with the timing of topic-specific public funding opportunities.

Little understanding of the business and legal aspects needed to successfully commercial their invention

Most entrepreneurs and early-stage companies have strong engineering and scientific backgrounds but little understanding and knowledge of the other aspects needed to successfully commercialize their invention. This includes identifying early beachhead markets; identifying optimal pathways to scale-up production and manufacturing; and protecting their intellectual property.

Lack of access to state-of-the-art facilities for rapid prototyping

State-of-the art equipment and facilities can significantly speed up the development of a new technology. The capital cost and permitting timelines of most testing and laboratory equipment is beyond what an entrepreneur or small start-up company can afford. While state-of-the-art equipment and facilities exist at universities and research institutions, most entrepreneurs are unable to gain access, in part due to costs.

"WE DEFINE THE INNOVATION ECOSYSTEM AS THE SET OF STAKEHOLDERS…THAT CAN COLLECTIVELY ENABLE THE COMMERCIALIZATION OF CLEAN ENERGY TECHNOLOGIES"
DEPARTMENT OF ENERGY, SUPPORTING CLEAN ENERGY STARTUPS[165]

In 2016, the Energy Commission launched the first phase of the California Energy Innovation Ecosystem to help early-stage innovators overcome these barriers.

This first phase is comprised of four regional energy innovation clusters and a small grant program. The regional energy innovation clusters provide and coordinate key entrepreneurial support services and resources for their respective regions. Collectively, the regional energy innovation clusters form a statewide network that serves as a clearinghouse for connecting entrepreneurs from around state into the California Energy Innovation Ecosystem.

The small grant program, called the California Sustainable Energy Entrepreneur Development Initiative or CalSEED, provides a recurring opportunity for entrepreneurs to apply for up to $150,000 in funding to test the feasibility of their energy concept.

164 Bockelt, Nathalie, *Bridging the Innovation Gap in the U.S. Energy System,* MIT Press, 2016

165 https://eere-exchange.energy.gov/FileContent.aspx?FileID=3d063488-c5e2-4850-b30e-c528945be2cc

In addition to the $150,000 in funding, applicants selected through CalSEED receive technical consulting and are also eligible to compete in a future business plan competition for an additional $450,000 to move from concept testing to prototype development. Through these two stages, CalSEED helps entrepreneurs demonstrate the early technical merits and commercial potential of their technology. CalSEED also helps entrepreneurs demonstrate they are capable of managing a small project, which provides an indicator for how well they will manage a larger project.

In addition to supporting entrepreneurship, CalSEED has a strong equity and diversity focus, including a subcommittee to increase participation from entrepreneurs from diverse background and underrepresented geographic locations of the state. The first call for proposals for CalSEED was held in February 2017, with more than 300 proposals received.

Table 40: Previous and Planned EPIC Investments on the Energy Innovation Ecosystem

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Small Grant Funding	California Sustainable Energy Entrepreneur Development (CalSEED) Initiative (300-15-007)	California Sustainable Energy Entrepreneur Development (CalSEED) Initiative (300-15-007)
Innovation Clusters	San Diego Regional Energy Innovation Cluster (EPC-15-030) Bay Area Regional Energy Innovation Cluster (EPC-15-032) Central Valley Energy Innovation Cluster: BlueTechValley Energy Cluster (EPC-15-038) Los Angeles Regional Energy Innovation Cluster (EPC-16-015)	San Diego Regional Energy Innovation Cluster (EPC-15-030) Bay Area Regional Energy Innovation Cluster (EPC-15-032) Central Valley Energy Innovation Cluster: BlueTechValley Energy Cluster (EPC-15-038) Los Angeles Regional Energy Innovation Cluster (EPC-16-015)

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

The 2018-2020 funding initiatives will continue to refine and possibly expand the Innovation Clusters and CalSEED activities established in the 2012 – 2014 and 2015 – 2017 Investment Plans. These initiatives provide important downstream benefits to the EPIC Program by raising the quality of technologies and proposals submitted to funding opportunities targeting mid- and later-stage technology development and demonstration.

Initiative 5.1.1 Continue CalSEED Initiative to Provide Early Stage Support for Clean Energy Technology Entrepreneurs

Description	This initiative will build upon the CalSEED Initiative efforts established under the first two EPIC Investment Plans. The small-scale funding provided by the CalSEED Initiative gives entrepreneurs starting capital to develop their ideas into proof-of-concepts and early prototypes. This level of funding fills a crucial niche in the financing landscape for clean energy entrepreneurs because venture capital firms have decreased their level of investment at this level over the past several years. This initiative will allow the CalSEED Initiative to reach more entrepreneurs throughout California
Impact if Successful	This initiative will enable clean energy technology entrepreneurs and startups to develop early stage ideas and concepts into proof of concept and prototype demonstrations. Innovations developed at this early stage can allow entrepreneurs to compete for follow-on funding from public or private sources to continue their technology development.
Primary Users and/or Beneficiaries	Clean energy entrepreneurs
Metrics and Performance Indicators	Increased diversity of clean energy entrepreneurs in California, number of technology developers able to increase the Technology Readiness Level of their innovations, number of new energy concepts successfully validated, increased amount of follow-on funding from public and private sector
Topic(s) Addressed	Entrepreneur Support
Value Chain	Grid Operations/Market Design Generation Transmission/Distribution Demand Side Management
Program Area(s)	Applied Research and Development

Initiative 5.1.2 Expand Entrepreneurial Services from Innovation Clusters

Description	This initiative will expand the entrepreneurial support provided by the Regional Energy Innovation Clusters funded under the first two EPIC Investment Plans by expanding the suite of commercialization assistance and services available for clean energy entrepreneurs and startups. This expansion will include increased access to laboratory testing facilities, and increased mentorship on business development, commercialization, scale-up and intellectual property considerations. While the focus of the initial set of Innovation Clusters were on supporting startups and entrepreneurs, this initiative will expand the Innovation Cluster resources and services to a wider spectrum of technology developers. These technical and non-technical resources create an ecosystem that fosters energy innovations at all Technology Readiness Levels. Additionally, while the existing innovation clusters are organized geographically, this initiative can create new innovation clusters focused on supporting specific technologies or market sectors.
Impact if Successful	Providing these technical and non-technical resources early in the technology development process will help increase the sophistication of clean energy entrepreneurs. Clean energy entrepreneurs will have a more comprehensive pathway for deploying their innovations. This will increase their likelihood of success when they are ready to compete for larger amounts of public or private funding.
Primary Users and/or Beneficiaries	Clean energy entrepreneurs, incubators, accelerators, national labs, universities, local economic development organizations
Metrics and Performance Indicators	Number of technology developers able to increase the Technology Readiness Level or Manufacturing Readiness Level of their innovations, increased amount of follow-on funding from public and private sector, shortened timeline for innovations to reach market, increased number of EPIC applicants that have used Innovation Cluster services.
Topic(s) Addressed	Entrepreneur Support
Value Chain	Grid Operations/Market Design Generation Transmission/Distribution Demand Side Management
Program Area(s)	Market Facilitation

Initiative 5.1.3 Cost Share for Private, Non-Profit Foundation, or Federal Clean Energy Funding Opportunities

Description	This initiative will expand the entrepreneurial support provided by CalSEED and the Regional Energy Innovation Clusters funded under the first two EPIC Investment Plans by providing cost share for follow-on private or non-profit foundation funding opportunities. This initiative will also continue the federal cost share efforts funded under the first two EPIC Investment Plans by providing cost-share for federal funding opportunities that are consistent with the goals and objectives of the EPIC program.
Impact if Successful	Providing cost share will increase the likelihood of success for clean energy entrepreneurs and researchers competing for public or private funding.
Primary Users and/or Beneficiaries	Clean energy entrepreneurs, researchers, incubators, accelerators, national labs, universities, local economic development organizations
Metrics and Performance Indicators	Number of technology developers able to increase the Technology Readiness Level or Manufacturing Readiness Level of their innovations, increased amount of follow-on funding from public and private sector, shortened timeline for innovations to reach market, increased number of EPIC applicants that have used Innovation Cluster services.
Topic(s) Addressed	Entrepreneur Support
Value Chain	Grid Operations/Market Design Generation Transmission/Distribution Demand Side Management
Program Area(s)	Market Facilitation

Table 41: Ratepayer Benefits Summary For Sub-Theme 5.1

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 5.1.1 Continue CalSEED Initiative to Provide Early Stage Support for Clean Energy Technology Entrepreneurs				X	X		X	X	X
Initiative 5.1.2 Expand Entrepreneurial Services from Innovation Clusters				X	X		X	X	X
Initiative 5.1.3 Cost Share for Private, Non-Profit or Federal Foundation Clean Energy Funding Opportunities				X	X		X	X	X

Source: California Energy Commission

5.2 Accelerate the Most Promising Energy Technologies from Prototype to Market Entry

Innovative clean energy technologies are often intended to displace incumbent technologies that have tremendous industrial inertia and established supply chains and manufacturing processes. Unlike software innovations, which can scale up at relatively low-cost, hard-tech innovations that work at prototype and bench scales can face a host of additional funding, engineering and design challenges on the way to scale-up. These challenges include:

"STARTUPS THAT ATTEMPT TO SCALE-UP FACE A NUMBER OF HURDLES WHEN MOVING FROM PROTOTYPE TO PRODUCTION"
MIT PRESS,
FROM STARTUP TO SCALE-UP[166]

Significant gaps between funding awards

For even the most promising energy innovations, researchers and technology developers typically require multiple rounds of public funding to advance their technology to a state where it can attract interest and investment from the private sector. However, the time between when a successful publicly-funded project ends to the time new public funding opportunities becomes available can be years apart. Even under a best-case scenario, this delay in funding can significantly slow the pace of a new technology's development.

Limited access to test beds to align technology designs with customer specifications

Clean energy entrepreneurs have difficulty making the leap from prototype to pilot scale demonstration of their technologies because they lack access to test bed facilities to validate their product design, performance and safety, and lack technical feedback to shift product specifications to meet the needs and wants of potential customers.

Challenges integrating emerging energy technologies into existing manufacturing

Most start-up companies are unable to secure the capital needed to build unique manufacturing capabilities for their technology. In addition, most are unfamiliar with local manufacturing capacity or how to interface with manufacturers. "Startups typically begin their searches online…to contract manufacturers based outside the U.S. This often means they can't work in close proximity to collaboratively resolve ongoing design problems, and they may also lose control of important aspects of their innovation."[167]

Competing in procurement opportunities

Large institutional customers with specialized energy needs – such as municipalities, hospitals, and the military – represent a crucial market opportunity for small-scale energy startup companies. These customers typically purchase energy technology solutions through formal procurement processes not well suited to the culture and resources of start-up companies. On the other side, startup companies don't often understand how to approach institutional customers or the procurement processes they are required to follow. As a result, California clean energy

166 http://dc.mit.edu/sites/default/files/doc/Connecting%20Startups%20to%20Small%20Manufacturers%20Nazemi%20July%202016.docx

167 Ibid

start-up companies miss out on opportunities to scale their businesses, and institutional customers miss out on new technologies that could potentially better address their needs.

Table 42: Previous and Planned EPIC Investments on Prototype to Market Entry

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Streamlined Follow-on Funding	No Projects	No current or planned investments
Test Beds	No Projects	Solicitation planned for release in 2017
Manufacturing Support	No Projects	No current or planned investments
Procurement Strategies	No Projects	Solicitation planned for release in 2017

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

The Energy Commission is currently developing a funding opportunity from the *EPIC 2015-2017 Investment Plan* to provide access to test beds for entrepreneurs; and to help facilitate greater inclusion of clean energy start-up companies in procurement processes. The 2018-2020 funding initiatives seek to fill additional gaps in California's energy innovation ecosystem by: providing a streamlined competitive process for successful projects to receive follow-on funding; and leveraging California's existing manufacturing facilities to help energy technologies scale from prototype to production without large capital expenditures.

Initiative 5.2.1 Bringing Rapid Innovation Development to Green Energy (BRIDGE)

Description

This initiative will establish a new funding mechanism to provide crucially needed follow-on funding for the most promising innovations that come out of EPIC and APRA-e. This support will allow researchers to continue their technology development without losing momentum or pausing to fund raise from private sources. Even the most promising energy innovations typically require multiple rounds of funding to advance their technology to attract private sector interest and investment. Public research programs like EPIC and ARPA-e can provide this support, but significant amounts of time can pass between opportunities on any given area of energy research. At best, these gaps in funding can kill the momentum on a promising innovation and delay the advancement of that innovation; at worst these gaps can stop development on an

	innovation altogether allowing potential breakthroughs to die on the vine. This initiative will aid in avoiding these costly delays and accelerate the development of the most promising energy technologies that have the potential to have a significant impact in the market.
Impact if Successful	Clean energy technology innovators will have a smoother path through the innovation pipeline increasing their chances of successfully brining a technology to commercial market. This initiative will also help reduce delays faced by technology innovators that result from a lack of secure funding sources
Primary Users and/or Beneficiaries	Energy researchers receiving EPIC or ARPA-E awards
Metrics and Performance Indicators	Number of EPIC or ARPA-E funded projects able to transition their innovations from an applied research stage to a demonstration stage
Topic(s) addressed	Entrepreneur support
Value Chain	Grid Operations/Market Design Generation Transmission/Distribution Demand-side Management
Program Area(s)	Applied Research and Development

Initiative 5.2.2 Connect Clean Energy Companies with Local California Manufacturing

Description	This initiative will support the development of new and innovative advanced manufacturing techniques, processes, and capabilities among local California manufactures to provide clean energy companies with access to high volume production technologies and expertise. Connecting energy companies with advance manufacturers early in the technology development process can help shorten the time and cost required for hardware scale-up and deployment. Material selection, assembly processes, and other engineering and design considerations can have dramatic impacts on the performance, reliability, and safety of a technology. Local manufacturers can inform these practical design considerations and help address them early in the technology development process before costly redesigns are needed later in the process. But manufactures themselves need to be equipped with the knowledge and capacity to properly support clean energy companies; this includes a highly-skilled workforce, and the

	ability to conduct rapid prototyping, rapid failure analysis, and scale-up of production volume. This initiative will also integrate with the efforts of the Regional Energy Innovation Clusters and the Governor's Office of Business and Economic Development by leveraging their network of entrepreneurs, research institutions, and business development experts to inject manufacturing support where it can make the largest impact on an innovations development.
Impact if Successful	This initiative will increase the ability of local manufacturers to support clean energy companies. Local manufacturers will be able to increase operations in California resulting in increased job creation and economic activity. Companies will be able to develop technology innovations that have an easier time integrating into manufacturing and supply-chain infrastructure, thus facing lower commercialization risk and become better prepared for scale-up.
Primary Users and/or Beneficiaries	Clean energy companies, California based manufacturers
Metrics and Performance Indicators	Increased manufacturing capacity in California, lowered time and cost for moving prototypes into production, increased amount of partnerships between clean energy companies and local manufactures.
Topic(s) Addressed	Clean energy company support, advanced manufacturing
Value Chain	Grid Operations/Market Design Generation Transmission/Distribution Demand-side Management
Program Area(s)	Market Facilitation

Table 43: Ratepayer Benefits Summary For Sub-Theme 5.2

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transpo rtation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 5.2.1 Bringing Rapid Innovation Development to Green Energy (BRIDGE)				X	X		X	X	X
Initiative 5.2.2 Connect Clean Energy Companies with Local California Manufacturing				X	X		X	X	X

Source: California Energy Commission

CHAPTER 7
Theme 6: Maximize Synergies in the Water-Energy-Nexus

The water-energy nexus refers to the linkage between water and energy systems. Water is used in energy production and by consumers, and energy is used in the extraction, treatment, transport to end users and discharge of water after use.

Many of the State's water and wastewater treatment plants are decades old and the pace of implementing new technological processes that are more efficient has been slow. This has been primarily due to limited budgets, cost-effectiveness, data gaps on baseline energy use, and reliability and performance of new technologies.

The industrial and agriculture sectors are large users of water. Water is used for irrigation of crops and raising livestock, and by industries for washing, cooling and sanitizing. Agriculture uses approximately 35 to 40 percent of the state's developed water supply.[168] For industries, the use of water also generates wastewater which varies in quality, quantity and contaminants. This has made treatment and reuse complicated and costly compared to use of fresh water.

The recent multi-year drought has resulted in some of the driest periods over the last five years, threatening water supplies of communities and residents, and affecting agricultural production and wildlife habitats.[169] In 2015 and 2016, Governor Brown issued two Executive Orders, B-29-15 and B-37-16.[170] These Executive Orders placed restrictions on water use, eliminating water waste, strengthening drought resilience, improving agricultural water efficiency and investing in new innovative water management technologies for businesses, residents, industries and agriculture. As a result of the executive orders, much attention was focused on developing and testing new technologies to reduce on-farm water use and on re-use of on-site generated wastewater. Many of these projects are still undergoing testing and development. For example, one project being tested helps agribusinesses quickly assess energy and water usage on mobile devices. Through customized alerts and reporting, the platform allows farms to quickly respond to changes in energy usage, adjust and optimize equipment in the field, and reduce operational expenses due to energy costs.

The funding initiatives described in this theme supplements the current portfolio of EPIC funded research projects and focuses on technology advancements and strategies to reduce the energy intensity in water supply and treatment, water use in the food and agriculture sector and optimize management practices. These initiatives are intended to accomplish the following:

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168 Comment from Carolyn Cook, California Department of Food and Agriculture, 3/22/2017
169 Executive Order B-37-6

170 https://www.gov.ca.gov/docs/4.1.15_Executive_Order.pdf

Develop low energy intensity treatment processes for conventional and non-conventional water sources, such as brackish water

California's continuing population growth has highlighted the need to increase water supply with the lowest environmental footprint. Increased supply is potentially available from non-conventional sources. Examples include desalinization and purification of contaminated or brackish water from groundwater aquifers. Some of the more promising reuse technologies are energy intensive, costly, and need validation to obtain regulatory acceptance. New technology advancements show promise to increase water supply, increase drought resilience, and reduce the energy associated with conveyance and water/wastewater treatment, such as use of new disinfection technologies and on-site re-use of wastewater.

"WE CANNOT ASSUME THE FUTURE IS LIKE THE PAST IN TERMS OF CLIMATE, TECHNOLOGY AND THE EVOLVING DECISION LANDSCAPE"
DEPARTMENT OF ENERGY, WATER ENERGY NEXUS: CHALLENGES AND OPPORTUNITIES[171]

Demonstrate cost-effective options for energy and water efficiency in agriculture and food processing to reduce its carbon intensity

The agricultural sector produces products valued at over $47 billion.[172] However, adoption of new technologies is slow primarily because of the short operating season which impact cost-effectiveness, risk aversion to try new technologies which could impact product quality, and regulatory changes which could impact water and energy resources and use. Demonstrations of new, cost-effective, low energy and water using technologies and approaches are needed to address the value proposition, long term product impacts, and regulatory acceptance of new technologies.

171 https://energy.gov/sites/prod/files/2014/07/f17/Water%20Energy%20Nexus%20Full%20Report%20July%202014.pdf

172 http://ajed.assembly.ca.gov/sites/ajed.assembly.ca.gov/files/Fast%20Facts%20on%20California%27s%20Agricultural%20Economy.pdf

6.1 Reduce the Energy Intensity Required to Supply and Treat Water

The energy used to extract, treat, and convey water and to treat and dispose of wastewater currently accounts for nearly 20 percent of California's electricity consumption.[173] The energy used in these phases is often referred to as the "embedded energy" in water. In the discharge phase, wastewater treatment is one of the largest expenses in local government budgets. It is also a sector in which energy use is growing. A 2013 study by the Electric Power Research Institute estimated a 74 percent increase in energy use in municipal wastewater treatment since 1996 and a 39 percent increase in energy usage for public drinking water systems.[174] The reasons cited were increasing demand due to increasing capacity and new regulations for upgraded treatment.

Much of the energy intensity associated with water systems is related to the use of pumps. Pumps are used in primary and secondary treatment systems to lift and convey water for backwashing filters, and for moving water through filters to remove salts and contaminants.

There are approximately 900 wastewater plants in California that range in size, age and the constituents of the water they receive for treatment.[175] These variations are reflected in the types of treatment processes and equipment at the plants. Many of California's current water and wastewater plants are 30 or more years old. Compliance with regulatory requirements enacted under the Clean Water Act and the Safe Drinking Water Act will require many water and wastewater systems to implement newer technologies such as ultraviolet light oxidation/disinfection, sequencing batch reactors, integrated membranes, and ozonation. However, there are many data and knowledge gaps that impact effective decision making on baseline energy use for these processes and how to make them more energy efficient.

"EFFICIENCY IS THE SMARTEST, CHEAPEST WAY TO SAVE MONEY AND EMISSIONS IN THE LONG RUN…BUT WE NEED TO DO IT ALL—EFFICIENCY AND NEW SUPPLIES—TO BE RESILIENT IN THE FACE OF CLIMATE CHANGE"
CHAIR FELICIA MARCUS, STATE WATER RESOURCES CONTROL BOARD[176]

In the industrial sector, water is used for various functions including producing feedstock, washing, mixing, cooling, and sanitizing. Through these uses, wastewater is discharged and there is wide variation in the quantities of and contaminants in the effluents. For example, beverages, food processing, dairy, chemicals and pharmaceuticals have very different wastewater profiles in terms of Biological Oxygen Demand, suspended solids, nitrogen and chlorides. These factors have served as challenges to the on-site treatment and reuse of water which saves energy in the water supply and discharge cycle.

173 www.energy.ca.gov/research/iaw/water.html
174 Electric Power Research Institute, Electricity Use and Management in the Municipal Water Supply and Wastewater Industries, November 2013, www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002001433
175 Laypersons Guide to Wastewater, Water Education Foundation, Abridged Version, 2013, www.watereducation.org/sites/main/files/file-attachments/lpg_wastewater_abridged.pdf .

176 http://www.planningreport.com/2016/11/29/role-water-data-california-s-conservation-efforts

Past EPIC research focused on a mix of applied research and demonstration projects, such as:

- Evaluating, testing and demonstrating novel treatment methods for non-conventional water supplies. These projects focus on anaerobic processes with gravity flow design and use of naturally occurring bacteria designed to remove particular contaminants.
- Demonstrating new technologies for on-site wastewater treatment and reuse. These projects focus on using forward osmosis/reverse osmosis to treat and reuse industrial wastewater.
- Testing and demonstrating new technologies to reduce the energy intensity of the wastewater treatment process through use of membranes and anaerobic treatment.

The goal of these projects was to demonstrate novel technologies to reduce the energy intensity of the treatment process and in some cases, result in removing contaminants to create new supplies for non-potable or potable reuse.

KEY TECHNICAL AND MARKET CHALLENGES

Some of the key technical and market challenges related to reducing energy intensity are improving energy efficiency and the cost-effectiveness in treatment processes through equipment and process improvements. There are many energy-related data gaps in the water sector that need to be filled. For example, good benchmark data is lacking on the appropriate energy use for various types of energy using equipment based on size, type, age and function. Good data is also needed to better understand the energy needed to process and handle activated sludge in wastewater treatment.

In the industrial sector, the on-site reuse of water has market barriers. The reuse of onsite water is very site-specific leading to customized design and regulatory considerations which could have cost implications. There are also regulations that inhibit the reuse of water that makes contact with final food products.

Energy efficient and cost-effective water treatment methods are needed to develop new water supplies from non-conventional sources

California's propensity for drought, dependence on transported water, and continuing population growth has highlighted the need to increase water supply. Increased supply is potentially available from non-conventional sources such as desalinization of seawater or from brackish water from groundwater aquifers that is contaminated with chemical constituents that can be removed so that the water can be reused. Some of the more promising technologies are biofiltration, distillation, forward osmosis, anaerobic fluidized bed technologies and methods to pre-filter water prior to treatment with reverse osmosis. However, these approaches are costly, the energy and full benefits are not adequately tested, and regulatory acceptance is uncertain.

Support development of tools and resources and methodologies such as advanced sensors coupled with controls that can help water and wastewater agencies optimize their operations to reduce carbon intensity

There is a need to improve communication capabilities among different types and vintages of equipment and processes at water and wastewater treatment facilities. The integration of advanced sensors, controls, and monitoring equipment with advanced energy efficiency technologies can provide operators with real-time energy information to better schedule or even automate certain operations. This can lower energy use and cost to match the needs of the grid or the treatment facility. However, there are many legacy control systems, each with their own operating systems which add to the complexity and cost to optimize.

Support energy efficiency improvements to equipment and technology used for industrial wastewater treatment for on-site water reuse

Economic, regulatory and technical barriers exist that can inhibit the advancement of technologies that can treat wastewater so that it can be reused for potable or non-potable uses. Examples of barriers include multiple permitting requirements, extensive and expensive testing and strict health, safety and rule making requirements. The pumping energy used to convey water from source to site is the largest part of the "embedded" energy in water. On-site water reuse avoids this energy use. The largest barrier to on-site reuse of industrial wastewater is the large variation in wastewater constituents which requires very site-specific design of the water capture and treatment systems and these can be very costly

Table 44: Previous and Planned EPIC Investments on Water Supply and Treatment

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Water Leakage	Demonstrating Innovative Leakage Reduction Strategies: Correlating Continuous Acoustic Monitoring, Satellite Imagery and Flow Sensitive Pressure Reaction Valve System (EPC-15-096)	No current or planned investments
Non-Conventional Water Supplies	Low Energy Biofiltration System with Low Backwash Rate for Groundwater Contaminant Removal (EPC-15-092)	Optimizing Use of Non-traditional Waters, Drought Proofing the Electricity System and Improving Snowpack Prediction 300-15-006 A New Solution to California's Energy and Water Challenges: Reducing the Cost of Desalination and Increasing Water Reuse (EPC-16-014) Low Energy, Zero Liquid Discharge Adsorption Technology to Remove Contaminants and Recover Source Water (EPC-16-006)
Wastewater Treatment Plants	Advance Wastewater Treatment Using Forward Osmosis to Produce High Quality Water (EPC-14-063) Improving Membrane Treatment Energy Efficiency through Monitoring the Removal of Colloidal Particle Foulants (EPC-15-012) Biofiltration as an Advanced Primary Treatment Method to Achieve Substantial Energy Savings (EPC-15-088) Raw Wastewater Filtration to Increase Organic Removal Efficiency and Achieve Significant Electrical Savings (EPC-14-076)	Novel Membrane Technology to Improve Energy Efficiency and Water Savings in Wastewater Treatment Operations (EPC-16-011) Maximizing Energy Efficiency and Reducing Bio-solids Waste from New Anaerobic Wastewater Treatment Technology (EPC-16-017) - Pending Biological Double-Efficiency Process as an Advanced Wastewater Treatment Method to Achieve Substantial Energy and Water Savings (EPC-16-018)

Source: California Energy Commission

2018 – 2020 FUNDING INITIATIVES

This subtheme aims to address some of the key technical challenges associated with supplying and treating water at the municipal and industrial level, and also developing and demonstrating new low-energy processes that allow use of non-conventional water sources to augment existing water supplies.

The first initiative focuses on developing and testing new energy efficient treatment methods for both conventional and non-conventional water supplies. The goal is to reduce the energy intensity of water treatment through system optimization and process improvements and use of new treatment methods while also looking to develop and test low-energy treatment processes for brackish and other non-conventional water sources.

The second imitative focuses on wastewater treatment and looks holistically at the carbon intensity of the entire treatment process and to identify opportunities to increase energy efficiency and electrify when technically and economically feasible. The outcome for this research will identify potential opportunities/strategies based on facility size, wastewater treatment process, and other parameters.

The third initiative focuses on full scale demonstrations of advanced, low energy treatment processes to allow for direct on-site reuse of the water for process or non-process purposes. The goal of the demonstrations is to show replicability and potential to be at least 20 percent more efficient than current processes.

Initiative 6.1.1 Develop and Test Novel Energy Efficient Treatment Methods for Conventional and Non-Conventional Sources of Water Supply

Description

This initiative will develop and test low-energy water or wastewater treatment approaches for conventional and non-conventional water sources, such as brackish water from inland groundwater aquifers. The goal is to reduce energy use intensity for water treatment. Areas of emphasis could include:

- Optimize ultraviolet and ozone disinfection technologies, including ultraviolet light emitting diodes that address fouling reduction and low-energy use
- System optimization of treatment plant and water distribution systems to balance energy optimization and operational flexibility including development of process controls, automation decision support tools and emote metering technologies for on-line efficiency improvement
- Advanced treatment systems to lower the energy use intensity needed to convert non-conventional water sources for community use, either as recycled water for non-

	potable applications, such as landscaping, or potable water production. These systems would consider the entire energy use of the treatment process (for example, aeration, sedimentation and sludge processing and disposal, disinfection and chemical removal) • Evaluate and test low energy intensity desalination for brackish water, including advance membrane materials that have the potential of reducing energy consumption by at least 20 percent.
Impact if Successful	This initiative will create ways to cost-effectively increase the efficiency of water treatment facilities, including those from non-conventional sources.
Primary Users and/or Beneficiaries	Drinking water and wastewater treatment facilities, communities that are impacted by limited water resources due to drought, pollution, location or natural geology
Metrics and Performance Indicators	Increased water yield, lower energy use compared to conventional approved treatment methods, and less waste for disposal.
Topic(s) addressed	Technical and Cost Advancements
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development

Initiative 6.1.2 Develop and Demonstrate Strategies to Help Wastewater Agencies Lower Energy Use, Increase Efficiency and Reduce the Carbon Intensity of its Operations

Description	Wastewater treatment plants use 200,000 MWh annually to treat and process wastewater. This initiative focuses on developing strategies to help reduce the carbon intensity of wastewater treatment and then implementing the strategy in multiple treatment plants in California. This initiative will demonstrate a holistic approach to reduce and the carbon intensity of the entire treatment process, to identify cost effective opportunities to increase energy efficiency and electrify when technically and economically feasible. Analysis will identify the resources and barriers to overcome what will be needed for full expansion into all wastewater treatment plants in California based on facility size (such as million gallons per day of water treated) and the potential target markets. Funded technologies and strategies must show a path to market for uptake by other treatment facilities if technical and economic feasibility are demonstrated. This initiative will

	also include measuring the energy benefits and cost savings, and greenhouse gas reductions and serve to benchmark the energy use of water and waste water related treatment processes and equipment. Monitoring and verification of pre- and post-treatment will be done using advanced sensors, controls and smart metering equipment.
Impact if Successful	Operators of wastewater facilities can prioritize future capital expenditures and determine which operations have the most potential for energy efficiency upgrades and take appropriate action in order to meet future state greenhouse gas reduction goal targets. The demonstrations will provide information to other wastewater facilities on what they can do in their facilities.
Primary Users and/or Beneficiaries	Wastewater treatment facilities
Metrics and Performance Indicators	Reduced energy costs, reduced greenhouse gas emissions, number of wastewater treatment plants using the developed strategies to improve the operating efficiency of their facility operations.
Topic(s) addressed	Technical and Cost Advancements
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development

Initiative 6.1.3 Develop and Demonstrate Advanced Energy Efficiency Improvements to Allow for On-Site Wastewater Treatment and Reuse for Industrial Facilities and Water Intensive Industries

Description	Water intensive industries, such as refineries, beverage companies, industrial scale laundries, pharmaceuticals and paper/pulp mills are major energy and water users. The water, which contains contaminants, is generally disposed into the sewer system. This initiative will focus on developing and demonstrating advanced, low energy treatment processes to allow for direct on-site reuse of the water, either for process or non-process (e.g., landscaping, toilet flushing) purposes. Examples of processes include advanced membranes that minimize maintenance and energy costs, or no membrane systems. The demonstrations will identify compatibility of low energy treatment processes and ability for retrofit into existing

	systems, capital and operating costs. The technologies must have the potential for high water reclamation relative to the amount of water to be treated and be at least 20 percent more efficient than current standard processes.
Impact if Successful	Energy use and costs will be reduced for industrial customers and water will be conserved. Ability to reuse water on-site reduces energy associated with transport, conveyance and treatment.
Primary Users and/or Beneficiaries	Various high water consuming industrial manufacturing facilities
Metrics and Performance Indicators	Reduced water consumption, energy savings, energy cost reduction, adoption by other water intensive industries.
Topic(s) addressed	Lower energy intensity of process water used in manufacturing
Value Chain	Demand-side Management
Program Area(s)	Applied Research and Development Technology Demonstration and Deployment

Table 45: Ratepayer Benefits Summary For Sub-Theme 6.1

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 6.1.1 Develop and Test Novel Energy Efficient Treatment Methods for Conventional and Non-Conventional Sources of Water Supply		X		X	X			X	
Initiative 6.1.2 Develop and Demonstrate Strategies to Help Wastewater Agencies Lower Energy Use, Increase Efficiency and Reduce the Carbon Intensity of its Operations		X		X	X			X	
Initiative 6.1.3 Develop and Demonstrate Advanced Energy Efficiency Improvements to Allow for On-Site Wastewater Treatment and Reuse for Industrial Facilities and Water Intensive Industries		X		X	X			X	

Source: California Energy Commission

6.2 Increase Energy and Water Efficiency of California's Food and Agriculture Sector

The agriculture and food processing industry in California is highly diversified. It processes more than 400 commodities that are sourced from California's 77,500 farms and ranches that collectively were valued at $47.1 billion in 2015.[177] Although food processing activities occur throughout the state, these industries are concentrated in the Central Valley. The Central Valley is home to more than 3,000 factory sites[178] including the world's largest sites for processing fluid milk (California Dairies, Inc.), cheese (Hilmar Cheese Company), milk powder/butter (California Dairies, Inc.), wine (E & J Gallo), and poultry (Foster Farms).

While many factors shape California's agriculture and food processing industry's path toward a sustainable and prosperous future, past research highlights indicate that the major challenges are resource conservation, environmental protection and global competitiveness. These driving forces require the food and agriculture sectors to face competing demands and increasingly difficult tradeoffs.

Added to these driving forces are uncertainty caused by California's ongoing drought conditions. The drought placed particular emphasis on development of irrigation efficiency technologies for the agriculture sector. Current Energy Commission research efforts focus on development of mobile phone app based software solutions for aggregating crop *and* field specific data *with* local weather conditions, water use (water meters or smart meter data), pump efficiency tracking, and pump energy consumption into actionable recommendation for farmers – without affecting crop yields or quality.

On-site facility water treatment and reuse has consistently been ranked as a high research area for the food production and processing sector.[179] Current research has focused on evaluating the use of forward osmosis for producing similar or higher quality beverage concentrates, purees, and purifying wastewater for on-site reuse. Research is also being conducted on the use of higher efficiency reverse osmosis systems for on-site wastewater reuse in the wine industry, and demonstrating innovative ways for livestock management that reduce heat stress while saving energy and water.

"WATER CONSERVATION AND REUSE PLAY IMPORTANT ROLES IN HELPING FARMERS AND RANCHERS ADAPT TO THE DROUGHT. PUBLIC AND PRIVATE PARTNERSHIPS MOVE INNOVATION AND AGRICULTURAL DIVERSITY FORWARD."

SECRETARY KAREN ROSS, CALIFORNIA DEPARTMENT OF FOOD AND AGRICULTURE[180]

KEY TECHNICAL AND MARKET CHALLENGES

California's agriculture and food processing industry faces a number of barriers to pursuing a sustainable and prosperous

177 California Department of Food and Agriculture
178http://www.energy.ca.gov/publications/displayOneReport.php?pubNum=CEC-500-2011-035, *PIER Industrial, Agricultural, and Water Energy Efficiency Program RD&D Targets: Consolidated Roadmap* - PIER Consultant Report, 2009.

179 Ibid.
180 http://www.energy.ca.gov/releases/2015_releases/2015-05-13_energy_water_saving_research_nr.html

future. The most significant barriers fall into the following areas:

Resource constraints

The success of agriculture and food processing industry is dependent on the availability of reasonably priced resources, especially energy and water. Shortages and unpredictable price fluctuations are barriers to operational efficiency and the competitiveness of both industries.

Technology gaps

The agriculture and food processing industry faces technical barriers associated with meeting on-site/field water use needs, wastewater management, thermal management, waste and byproduct disposal and reuse, and food processing operations.

Limited and Seasonal Operations

The agriculture and food processing sectors are highly seasonal and many operate for only a few months annually. This makes the economics difficult, because there are fewer months to spread the savings. This also means that equipment often sits idle for many months of the year.

Also replacement of major equipment results in factory downtime which reduces revenue. As profit margins are tight and the agriculture and food processing sectors are highly competitive and seasonal, any loss of revenue is a major concern to industries.

Table 46: Previous and Planned EPIC Investments on Energy and Water Efficiency

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Irrigation Efficiency	Wexus Energy and Water Management Mobile Software for the Agricultural Industry (EPC-14-070) Irrigation Optimization and Well Pump Monitoring to Reduce Energy and Water Consumption (EPC-14-081) Energy Efficiency and Water Savings in Agriculture by Innovative Plant-Aware Irrigation System (EPC-15-091)	Increased energy efficiency via programmable irrigation and fertilization (EPC-15-051) - Pending
Onsite Energy Savings Associated with Water Treatment, Reduction, and/or Reuse	Demonstration of Forward Osmosis to Produce Juice Concentrate, Purify and Reuse Wastewater and Reduce Energy Use (EPC-14-065) Winery Water and Energy Savings (water treatment for indoor use and heat exchanger for process improvement) (EPC-15-050)	Improving Water and Energy Efficiency in California's Dairy Industry (EPC-16-010) Testing a Low-Energy Water Treatment System for Fail-Safe Direct Potable Reuse (EPC-16-009)

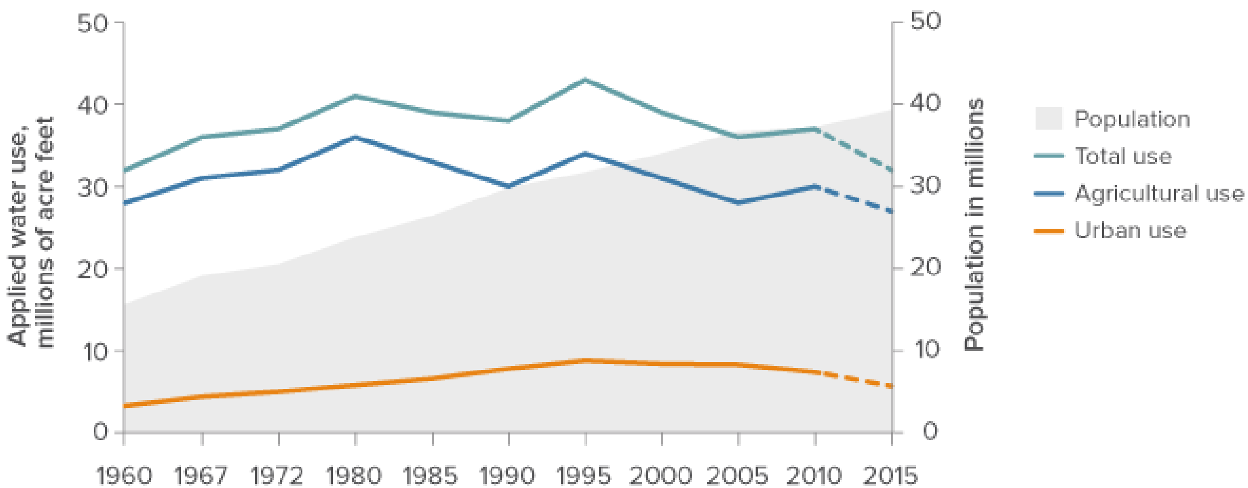
Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

For the third EPIC investment cycle, the focus will be on demonstration and deployment of emerging site-specific energy and/or water efficiency technologies for agriculture operations or food processing facilities.

The first initiative focuses on addressing one of the major agriculture challenges facing the industry: keeping energy costs low. Approximately nine million acres of farmland are irrigated and this is about 80 percent of all water used for business and homes.[181] Technologies and strategies are needed to help growers and farm operators manage their water use and keep energy costs low. Technologies must be well demonstrated over several seasons to show actual and sustained benefits to justify the investment without affecting crop yields or quality.

Figure 11 Agriculture and Urban Water Use



Source: Public Policy Institute of California, "Water Use in California."[182]

The second initiative focuses on the food processing industry and addressing the challenges associated with reducing investment risk, operating costs and greenhouse gas emissions while maintaining or improving finished products. In addition, technologies must be demonstrated over multiple seasons to show actual benefits and cost effectiveness, such as simple payback of less than 5 years – so electric utility incentives will be an important factor in driving down costs. This industry is also very concerned about the future environmental challenges associated with the need and cost to reduce greenhouse gas and decarbonize. Thus, this initiative focuses on identifying technologies that will help them to meet these challenges cost effectively without impacting their business operations or product quality.

Demonstrations of innovative technologies under actual real world conditions are needed to validate performance and cost savings.

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181 Public Policy Institute of California, "Water Use in California," 2016. http://www.ppic.org/main/publication.asp?i=1108
182 Ibid.

Initiative 6.2.1 Demonstrate Advanced Water and/or Energy Efficiency Technologies to Reduce Carbon Intensity of Agriculture

Description	This initiative will demonstrate advanced technologies to reduce energy and water use in varying regions and crop types. Examples of technologies to be demonstrated could include those that use deficit irrigation, precision agriculture and ultra-efficient drip irrigation systems with high distribution uniformity. Demonstrated technologies will be independently monitored for energy and water savings and crop yield (e.g., yield/volume of water used) over several seasons.
Impact if Successful	Increase probability of the agricultural sector implementing demonstrated technologies if verified performance data is available.
Primary Users and/or Beneficiaries	California's agricultural sector
Metrics and/or Performance Indicators	Reduced on-site energy/water use, improved productivity, reduced wastewater discharge
Topic(s) addressed	Energy and/or Water Efficiency
Value Chain	Demand-side Management
Program Area(s)	Technology Demonstration and Deployment

Initiative 6.2.2 Demonstrate Advanced Energy and/or Water Efficiency Technologies to Reduce Carbon Intensity of Food Processing Operations

Description	The food processing industry is faced with many challenges. Foremost among those challenges are wastewater and waste management, thermal management, regulatory burdens and high operating costs. This industry is also very risk adverse. As a result, new technologies must be demonstrated over multiple seasons to show actual benefits and cost effectiveness, typically with a simple payback of less than 5 years. This industry is also very concerned about the future environmental challenges associated with the need and cost to reduce greenhouse gas and decarbonize. This initiative will demonstrate technologies with potential for cost effectiveness that will not impact their business operations or product quality while addressing the best opportunities to reduce

	carbon intensity of their operations. For each technology to be demonstrated, the team must include a food processing facility and an equipment manufacture that has the potential to make the technology production ready, if successful. Advanced technologies to be demonstrated can include: • Process efficiency improvements that can include advanced motors and pumps and compressed air system improvements • Advanced energy management controls for fault detection and diagnostics, and control and monitoring of motors, pumps and compressed air systems for optimal efficiency • Refrigeration systems, including those using alternative refrigerants that are low global warming and low greenhouse gas emitting • Advanced on-site water/wastewater systems including novel treatment systems to allow for on-site reuse • Implementation of opportunities to cost-effectively decarbonize including waste heat recovery, onsite generation using renewable energy sources
Impact if Successful	This initiative will increase probability of the food processing sector implementing demonstrated technologies if verified performance data is available
Primary Users and/or Beneficiaries	California's food processing sector
Metrics and/or Performance Indicators	Reduced on-site energy/water use, improved productivity, reduced wastewater discharge
Topic(s) addressed	Energy and/or Water Efficiency
Value Chain	Demand-side Management
Program Area(s)	Technology Demonstration and Deployment

Table 47: Ratepayer Benefits Summary For Sub-Theme 6.2

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 6.2.1 Demonstrate Advanced Water and/or Energy Efficiency Technologies to Reduce Carbon Intensity of Agriculture	X	X		X	X			X	
Initiative 6.2.2 Demonstrate Advanced Energy and/or Water Efficiency Technologies to Reduce Carbon Intensity of Food Processing Operations	X	X		X	X			X	

Source: California Energy Commission

CHAPTER 8
Theme 7: Develop Tools and Analysis to Inform Energy Policy and Planning Decisions

California has adopted ambitious policy goals for transforming its electricity system. "There are many technical, market, and policy challenges related to how electricity sector investment decisions and operations, federal and state policy regulations, and system and policy planning interact with efforts to shift to a low-carbon electricity system."[183] For policymakers and other stakeholders, making informed decisions can be challenging without more sophisticated analytical tools and scientific analysis capable of evaluating the complexities and implications of different strategies.

"EHANCEMENTS TO EXISTING ELECTRICITY SECTOR MODELS WILL BE REQUIRED AS CLIMATE CHANGE AND OTHER CHALLENGES AFFECT THE ELECTRICITY SYSTEM"
DEPARTMENT OF ENERGY, SECOND INSTALLMENT OF THE QUADRENNIAL ENERGY REVIEW[184]

The funding initiatives described in this chapter focus on identifying optimal pathways for achieving California's energy and climate goals, increasing the resiliency of the electricity system to climate change and extreme weather events and evaluating strategies to mitigate the impacts of the electricity system on the environment and public health and safety. Theme 7 "…also supports increased interagency collaboration on climate adaptation planning and actions, which will help streamline the flow of information to California's agencies and avoid duplication of effort."[185]

Identify Pathways for Achieving California's Energy and Climate Goals

As the state's electricity system transforms to meet the energy and GHG reduction targets of SB 350 and SB 32, new issues and challenges have and will continue to emerge. Various studies have shown that California can achieve its greenhouse gas emission controls through a variety of pathways, but detailed long-term planning of how the energy system will evolve is necessary to understand how these emission goals can be achieved, to understand the effects of existing and future policies and to understand the resulting economic and environmental consequences of alternative energy system development.[186] Unbiased analysis is needed to identify and assess the potential for near- and long-term technology options to meet these and future demands of the electricity system. To facilitate greater adoption of measures necessary to achieve

183 https://www.energy.gov/epsa/downloads/quadrennial-energy-review-second-installment.
184 Ibid.

185 Pacific Gas and Electric Company Comments on the Draft 2016 IEPR Scoping Order. March 4, 2016. http://docketpublic.energy.ca.gov/PublicDocuments/16-IEPR-01/TN210617_20160304T155350_Nathan_Bengtsson_Comments_Pacific_Gas_and_Electric_Company_Comm.pdf.
186 Morrison et al. 2015. Comparison of low-carbon pathways for California. April. https://www.researchgate.net/publication/275642122_Comparison_of_low-carbon_pathways_for_California

the state's greenhouse gas emission goals, research under this subject area will also address the behavioral aspects of new technology acceptance.

"SYSTEMATIC ECONOMIC ELECTRIFICATION FOR SHIFTING FROM DIRECT FUEL USE IS OFTEN TECHNICALLY MORE DIFFICULT AND EXPENSIVE FOR INDUSTRY"
DEPARTMENT OF ENERGY, SECOND INSTALLMENT OF THE QUADRENNIAL ENERGY REVIEW[187]

Increase the Resiliency of the Electricity System to Climate Change and Extreme Weather Events

California's electricity sector is highly vulnerable to challenges that climate extremes, such as heat waves or drought will pose to energy generation and demand; while catastrophic events such as wildfires or severe flooding will severely impact the state's energy infrastructure. As a result, changes in one part of the electricity system can have significant impacts on other elements of the electricity system as well as other sectors. Research in this subject area lays a scientific foundation and provides practical tools for anticipating and adapting to climate and weather-related challenges to the electricity sector, ensuring the system's resilience and cost-effectiveness in the face of climate change.

"FURTHER ANALYTICAL TOOLS ARE NEEDED … TO BETTER FRAME SYSTEM-LEVEL TRADEOFFS REALTED TO RESILIENCE, ECONOMICS, ENVIRONMENTAL IMPACTS, AND OTHER FACTORS"
DEPARTMENT OF ENERGY, SECOND INSTALLMENT OF THE QUADRENNIAL ENERGY REVIEW[188]

Evaluate Strategies to Mitigate the Impacts of the Electricity System on the Environment and Public Health and Safety

As California strives to meet its greenhouse gas emission targets, it is critical that the full environmental effects, including lifecycle considerations, of today's emerging clean energy technologies be understood. This includes not only environmental information needed to facilitate renewable energy siting, but potential health effects as well, with an emphasis on health risks in environmental justice/disadvantaged communities.

Emerging renewable energy technologies will play a major role in the state's future energy system and pose environmental considerations that may affect facility siting. These issues may occur in currently developed areas, or in areas not historically used for energy generation, such as off the California coast. Research identified in this initiative will provide the environmental information relating to future renewable energy deployment so that decision-makers can select or influence energy development following one of the most environmentally benign paths.

187 https://www.energy.gov/epsa/downloads/quadrennial-energy-review-second-installment.

188 Ibid.

7.1 Identify Pathways for Achieving California's Energy and Climate Goals

Fundamental transformations to California's energy system are necessary to achieve California's ambitious mandate of 40 percent GHG emission reduction by 2030 and 80 percent reduction by 2050. EPIC must invest strategically in energy technologies with the potential to substantially reduce GHG emissions from the electricity sector while limiting and decreasing costs where possible. The strategy, in other words, needs to move beyond the investment of energy technologies that yield only incremental GHG reductions.

Early results from EPIC-funded studies (EPC-14-072, EPC-14-074, and EPC-14-069) reveal that there are two necessary pillars to support strategic investment in fundamental transformation of the electricity sector.

First, energy technologies cannot be considered in isolation. Synergies among energy technologies across sectors as well as interactions with other state mandates and priorities and equity efforts can have profound impacts on the performance and adoption of technologies. As technologies are being developed and deployed, these interactions must be incorporated into research and planning to leverage these synergies.

For example, during the April 11, 2017 "Customers of Climate Science Research" workshop, the Asian Pacific Environmental Network (APEN) offered the following suggestions to ensure equity considerations are taken into account in infrastructure and emergency preparedness planning efforts:

- Locate advanced storage systems and other innovative energy-resiliency technologies in facilities used by essential local service providers, including food banks, churches, and community centers.
- Identify and mitigate hazards that could pose public health and safety risks in extreme weather, such as abandoned oil wells and refineries.
- Direct resources to communities with high exposure and vulnerability to extreme weather, including areas covered with impervious pavement prone to flooding; homes and buildings with limited access to air conditioning; neighborhoods with a high number of renters; and regions with a large proportion of outdoor workers.

In addition, utilities at the April 11 workshop highlighted the following needs to facilitate incorporation of climate science research into planning:

- Establish an agreed upon set of climate change planning factors for utility infrastructure investments.
- Provide GIS data layers and seasonal forecasting tools for utility resiliency models to specify where, when, and how climate is projected to impact hydrology, fire risk, cooling-degree days, and inundation risk.
- Provide interactive scenarios for combined impacts of multiple concurrent or sequential extreme events. Consider how extreme weather in one part of California could impact utility operations in other parts of the state. Examples include: 1) summer heat storms combined with closure of a key facility (such as the Aliso Canyon gas storage facility); or 2) prolonged

drought followed by wildfire, severe storms, and flooding.

Descriptive and scientifically rigorous climate change scenarios are critical achieve California's long-term energy goals. For example, prior modeling suggested the need for deep electrification.[189] That study's findings were later supported in ARB's Scoping Plan. EPIC, alongside other state funding mechanisms, has made notable improvements in the electricity sector. But, the new energy system is still evolving. As a result, decision support tools must be updated to provide a publicly available scientific basis to inform resiliency planning for California's energy system.

This theme fosters strong, scientifically rigorous studies integrating research results from other themes. Advances in new EPIC-funded technologies will be examined to identify and execute beneficial synergies and overcome potential negative interactions. This approach includes identifying implications on other energy technologies from a system-wide approach. For example, a study found the widespread use of electric heat pumps for space heating could create a new winter peak electricity load.

This theme builds from a solid foundation of prior EPIC-funded and PIER research. The Energy Commission has contributed to the development of energy models and the examination of potential pathways associated with deep decarbonization of the energy system. For example, prior modelling efforts contributed to the understanding that electrification of energy services (e.g., space heating, mobility) coupled with decarbonization of the electricity grid is a very attractive option to drastically reduce carbon dioxide emissions.[190,191] Currently, EPIC research is examining the most likely costs of electrification in various sectors of the economy and the implications that a changing climate may have on "optimal" energy pathways.

Early research results have shown that the simultaneous consideration of mitigation and adaptation provides important information that can be used to make choices in energy investment and deployment. For example, research indicates that increased temperatures will reduce the capacity of thermal power plants and increase peak electricity demand unless adaptation measures are implemented.[192] This has implications for long-term investment and the CPUC's Long Term Planning and Procurement process as well as IOUs' individual climate resilience responses. However, although the long term energy scenarios are breaking new ground, the incorporation of adaptation alongside mitigation as inputs to the models is still at the preliminary stages. Further work will need to be done to more fully integrate these two catalysts for the transformation of California's energy system. Doing so will reduce uncertainty in decisions regarding when and how to deploy particular technologies to meet California's policy goals while still building a climate-resilient energy sector for IOU ratepayers.

189 Wei, M., Nelson, J.H., Greenblatt, et al., (2013). "Deep carbon reductions in California require electrification and integration across economic sectors." Environmental Research Letters. 2013;8:014038.

190 Wei, M., Nelson, J.H., Greenblatt, et al., (2013). "Deep carbon reductions in California require electrification and integration across economic sectors." Environmental Research Letters. 2013;8:014038

191 Wei, Max; Jeffery Greenblatt; Sally Donovan; et al., (2014). Scenarios for Meeting California's 2050 Climate Goals. California Energy Commission. Publication number: CEC-500-2014-108.

192 Sathaye, J.A., L. Dale, et al. (2013). Estimating impacts of warming temperatures on California's electricity system. Global Environmental Change.

To summarize the need for this theme and its relationship to prior work: previous energy scenario work has indicated potential pathways to reach 2030 and 2050 energy goals; but, further work is needed to address the interaction of new technologies under development, among other critical challenges discussed above. As new energy technologies come on line and climate impacts unfold, it is essential to have up-to-date scenarios and modelling work to offer pathways for the energy sector to achieve climate adaptation, equity, and other clean energy policy goals quickly, safely, and affordably.

KEY TECHNICAL AND MARKET CHALLENGES

Building on previous achievements, future work in modelling and scenario development is needed to provide more specific information on climate vulnerability and the energy sector. Although California has been a national leader in studying climate impacts, detailed studies that take into account the facilities, operations, and infrastructure, and management options that comprise California's future energy system are nonetheless too few to build robust inputs into models. For example, oscillations between extreme drought and flood may lead to previously unexplored vulnerabilities to water-sensitive infrastructure. The solution to this challenge for future modeling work is to garner information from subtheme 7.2. This information must be captured in the energy models to be developed and used under this theme. This will ensure the models' ability to inform strategies that lead to California's emission reduction goals and, a more resilient energy system.

Table 48: Previous and Planned EPIC Investments on Pathways to Achieve California's Energy Climate Goals

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Energy Scenario Development	Develop Analytical Tools and Technologies to Plan for and Minimize the Impacts of Climate Change on the Electricity System (EPC-14-069) Building a Healthier and More Robust Future: 2050 Low Carbon Energy Scenarios for California (EPC-14-072) Building a Climate Change Resilient Electricity System for Meeting California's Energy and Environmental Goals (EPC-14-074)	Holistic View of Urban Energy Planning for Microgrids, Deep Energy Efficiency in Buildings, Electrification, and Environmental Justice/Equity issues (forthcoming solicitation)
Research Roadmaps	Research Roadmap for Advancing Technologies in California's Industrial, Agricultural, and Water Sectors (300-15-010) Research Roadmap for Getting to Zero Net Energy Buildings (300-15-008)	Research Roadmap for System Transformations to Enable High Penetration of Distributed Energy Resources (forthcoming solicitation) Research Roadmap for Advancing Renewable Energy Technologies (forthcoming solicitation)
Demand Forecasting	California Commercial End-Use Survey (300-15-011) California Investor-Owned Utility Electricity Loadshapes (300-15-013) Examining the Heterogeneity of Energy Efficiency Adoption and Savings Across Socio-Economic and Ethnic Groups Using a Large Scale Quasi-Experiment (EPC-14-026) Capturing Cultural Diversity in California Residential Energy Efficiency Potential: An Energy Ethnography of Hispanic Households (EPC-14-032) Home Energy Efficiency Retrofits in California: An Analysis of Sociocultural Factors Influencing Customer Adoption (EPC-14-037) Fieldwork to Document Technology Adoption and Behavior Change Across Diverse Geographies and Populations to Inform Energy Efficiency Program Design (EPC-14-083) Cultural Factors in the Energy Use Patterns of Multifamily Tenants (EPC-14-039) Historical Insights for Electricity Transition Scenarios in California and Flexible Energy Demand Modeling for Residential Air Conditioning with Improved Behavioral Specificity (EPC-15-081) Identifying Effective Demand Response Program Designs to Increase Residential Customer Participation (EPC-15-073)	Probabilistic Seasonal and Decadal Forecasts for the Electricity System Using Linear Inverse Modeling (EPC-15-036).
Realistic Options for Electrification	No projects	Pathways to More Cost-effective Homes (EPC-16-002). Real World Electrification Options of Energy Services and Environmental Justice (EPC-15-028)

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

The 2018-2020 funding initiatives under Sub-theme 7.1 are designed to address the research gaps identified above but building on what past Energy Commission research accomplished so far.

Initiative 7.1.1 Integrated Pathways for Energy Futures: Tools and Science-Based Research for Holistic Energy Decision Making

Description	This research will examine and model promising energy technologies to prioritize their potential contributions to deep GHG emissions reductions. This work will be coordinated with other proposed initiatives to properly consider effects of climate change and the interactions between the water and energy sectors. Broadly speaking, this sub-theme tackles four different areas in an integrated/holistic way: • Interdependences between sectors. There is a growing need to respond to risks of systemic failure through interdependencies across systems connected to the energy sector—including, but not limited to water and telecommunications—as expressed by the CPUC in its 2016 Annual Safety En Banc. This initiative builds off of ongoing work in Southern California for the state's Fourth Climate Assessment (EPC 15-080 and EPC 15-005). For example, as presented at the 2016 Annual Safety En Banc, in 2003 rolling electricity blackouts in the Northeastern United States led to raw sewage overflows in New York, and unavailability of potable water. During the same blackout communications between electricity providers and safety officials "failed due to lack of adequate capacity and backup power."[193] Climate change disturbs and exacerbates these interdependencies through natural hazard (flooding, sea level rise, drought, and wildfire) as well as through system responses to hazards (blackouts, changes in energy and water use, among others). These system responses are sometime called "secondary climate impacts" and are highlighted in the California Public Utilities Commission's "Key Takeaways from 2016 Safety En Banc":

193 California Public Utilities Commission, Case Study, 2016 Safety En Banc. http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Safety/2016%20Safety%20En%20Banc%20Case%20Study.pdf

	• Interactive tools to prioritize technology choices from now to 2050. This effort must be informed by the Integrated Resource Plans that IOUs are preparing. Additionally, since these plans only reflect what may happen in the next decade, this effort will examine a long-term perspective to 2030 and 2050. Interactive tools would allow quick analyses of technology choices using considering all energy services such as space heating, illumination, and mobility. • Regional variations relative to interdependences and technology choices. Most of the existing energy models for California are statewide models that simulate California as one block. For this reason, this research includes in-depth integrated and holistic analyses of urban areas and regional studies to allow more detailed consideration of factors, such as geographical distribution of demand and local resources. Urban and regional studies are more likely to accomplish this resolution than large statewide studies. This will also consider items (1) and (2) described above. • Consideration of equity. The long-term energy scenarios must investigate equity issues, such as the potential costs and the benefits of electrification for disadvantaged and low income communities, because the electrification of energy services (e.g., electric cars and trucks) can result in drastic reduction of ambient air pollutants such as particulate matter and oxides of nitrogen. The final outcome may have the ancillary benefit of achieving national ambient air quality standards in the San Joaquin and Los Angeles air basins. This work will address issues and urban areas not covered under the second EPIC Investment Plan and advance methodology issues such as improved representation of interconnected community microgrids.
Impact if Successful	This initiative brings together technological and scientific advancements, as well as external factors, and integrates them into a cohesive whole. In doing so, this research will help prioritize technology research, inform technology selection, and potentially inform regulatory and policy proceedings that can help California effectively achieve long-term system decarbonization goals.
Primary Users and/or Beneficiaries	Policy makers, IOUs, and the public in general

Metrics and/or Performance Indicators	Research findings that are adopted formally or informally by energy agencies and/or IOUs Publications in peer-reviewed journals. Adoption of models or their derivatives in models used for formal regulatory and/or policy deliberations.
Topic(s) addressed	Energy Modeling
Value Chain	Generation Transmission/Distribution Demand-Side Management
Program Area(s)	Applied Research and Development

Initiative 7.1.2 Applied Social Science Research to Inform Technology Development and Adoption for Deep Decarbonization of the Energy System

Description	Technology solutions are incomplete if users do not adopt them or do not use them effectively (e.g., negating technology energy efficiency gains with counterproductive behavior). Energy modeling assumes consumer adoption of the "best" technologies evaluated in technical terms that do not account for diverse consumer preferences. Research under this subtheme will target applied behavioral research and/or some level of behavioral components to facilitate the deep penetration of technologies supported by EPIC. This work will be heavily coordinated with EPIC III research on behavioral issues associated with demand response and distributed electricity generation. This research will be implemented by interdisciplinary teams to minimize the problem of not considering the new advances in social marketing, economics and social sciences in technology development and deployment.
Impact if Successful	The findings would enable wide-scale, rapid, and cost-effective deployment of clean energy technologies.
Primary Users and/or Beneficiaries	Policymakers, energy agencies, IOUs, project developers, and product developers
Metrics and Performance Indicators	• Number of publications in scientific and policy journals. • Number of findings that are incorporated in energy products.

Topic(s) addressed	Applied social science research to improve product development
Value Chain	Generation Demand-Side Management
Program Area(s)	Market Facilitation

Table 49: Ratepayer Benefits Summary For Sub-Theme 7.1

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 7.1.1 Integrated Pathways for Energy Futures: Tools and Science-Based Research for Holistic Energy Decision Making	X	X		X	X			X	
Initiative 7.1.2 Applied Social Science Research to Inform Technology Development and Adoption for Deep Decarbonization of the Energy System		X		X	X			X	

Source: California Energy Commission

7.2 Increase the Resiliency of the Electricity System to Climate Change and Extreme Weather Events

California's electricity system is vulnerable to a variety of extreme weather events, including droughts, heat waves, wildfires, and coastal as well as inland flooding. Climate change will exacerbate many threats associated with extreme weather, making resilience a greater challenge. Already, weather patterns are shifting away from historical norms and aggravating familiar climate-related challenges, such as drought and wildfire, to California's electricity system.

Research in this subject area lays a scientifically rigorous foundation for anticipating and adapting to climate and weather-related challenges, thereby preserving electricity sector resilience and cost-effectiveness in the face of climate change. Specifically, this research clarifies the nature, timing, and magnitude of climate-related challenges that California's electricity sector must prepare for; illuminates interactions between climate change and renewable energy systems to ensure that California's energy transition capitalizes on opportunities while reducing risks; delineates actions needed to reduce risks to the electricity system; and fosters actions to bolster electricity sector resilience through provision of tools, understanding of barriers, and consideration of interconnected systems.

EPIC funded research in this area contributed to the delineation and adoption of consistent scenarios for energy sector research and planning through the 2016 IEPR process. This major milestone responds to needs expressed by the CPUC, the Energy Commission, and the IOUs, namely that California's electricity utilities need clear direction regarding what climatic conditions to plan for. Alignment of the Governor's Office of Planning and Research (OPR) adaptation guidance with these scenarios underscores the impact of EPIC-funded research and further ensures that electricity system resilience efforts are aligned with California's broader approach across sectors and geography.

KEY TECHNICAL AND MARKET CHALLENGES

This research addresses the technical challenges of clarifying more precisely what climate risks California's electricity sector will face, how to effectively respond, and how to integrate response options into utility operations. To that end, this research must build on the Energy Commission's success in engaging IOUs and CAISO throughout the process to ensure that researchers are asking the right questions, delivering results in an appropriate format, and leveraging the necessary institutional capacity and human networks to integrate new knowledge into operations.

Key challenges in this area include anticipating not only risks to the existing electricity system—which is the dominant focus of past, ongoing, and planned research—but also anticipating climate-related risks to the additional renewable capacity that California is building to meet its ambitious climate and energy goals. This challenge will be addressed by Initiative 7.2.2.

Another major challenge is bridging the gap between producing *actionable information*, and robustly *informing action*, which may require additional research to develop operational tools and guide decision-making in relation to interconnected systems. This challenge will be addressed by initiative 7.2.3.

Because Initiatives 7.2.2 and 7.2.3 will need to be informed by highly specific understandings of how climate change will play out at a very local scale, parameters of interest to IOU operations and infrastructure management will need to be considered in the projections and probabilistic forecasts produced by Initiative 7.2.1. Downscaling translates coarse-resolution results produced by Global Climate Models to detailed scenarios that illuminate how climate change is expected to play out at a local scale. The projection of changes at a local scale and with a time resolution that can inform operations provides the foundation for *actionable* adaptation.

Develop high-resolution climate change projections, assess risks, and develop resilience options

The energy sector must identify climate-related risks to infrastructure and operations with a level of detail that enables identification and execution of actionable resilience strategies. The foundation for identification of risks and resilience strategies is high-resolution projections that clarify changes in local climate parameters.

Ongoing research in the area of projections is developing probabilistic methods to integrate climate change into seasonal and decadal forecasts as well as hydropower operations. Research is also developing new, technically advanced regional climate downscaling methods that can represent additional phenomena of interest to the electricity system (e.g., Delta Breeze, Santa Ana winds) as well as increase the spatial or temporal resolution of parameters that affect risks to assets, generation (e.g., sub-daily wind speed), transmission, and demand. Projections of additional parameters would be responsive to guidance from IOUs and other electricity stakeholders.

Ongoing research in the area of vulnerability assessment and resilience options is clarifying potential impacts of wildfire on transmission and distribution, grid vulnerability to extreme heat in the Los Angeles area, and coastal vulnerability of SDG&E's electricity sector assets.

Methodology for improved hybrid projections that leverage the advantages of statistical downscaling and dynamical downscaling is being developed under ongoing research. This will enable exploration of additional vulnerabilities—such as those related to coastal upwelling and related impacts on demand—to the electricity system under initiative 7.2.1. This initiative will also support research regarding "win-win" strategies, which offer benefits under current (highly variable) climatic conditions as well as those anticipated in the future. In an example of such "win-win" strategies, short-term probabilistic forecasting models could be developed to predict the timing, location, and magnitude of precipitation associated with Atmospheric Rivers (ARs) in California. For example, if the timing, location, and magnitude of AR precipitation could be reliably forecast three days in advance, these forecasts could provide a basis for modifying reservoir operations and improving their benefits with regard to providing hydropower resources as well as flood control under both current and future climates.

Clarify interactions between climate change and renewable energy systems.

Shifting California's electricity system to renewable energy is both a central component of the state's strategy for reducing emissions of climate pollutants *and* an endeavor that must anticipate and respond to climate change so that it is effective in achieving its goals.

Ongoing research will clarify how large-scale solar installations may affect desert soil carbon cycles and how to address weather-related barriers to wind energy expansion in the state.

Future research (identified in initiative 7.2.2) would investigate how climatic change may shift the availability and distribution of wind, and solar resources through impacts on parameters such as peak wind speeds, solar irradiation, and cloud cover. As articulated in Subtheme 7.1, clarification of the spatial distribution and timing of changes in these renewable resources is essential to informing optimal long-term energy strategies.

"PG&E SUPPORTS THE NOTION OF ACTIONABLE RESEARCH THAT CAN LEAD TO TANGIBLE IMPROVEMENTS; MORE STANDARDIZED CLIMATE SCENARIOS, GUIDANCE, AND DOWNSCALED CLIMATE DATA TO SUPPORT RESILIENCY PLANNING; AND ENHANCING TOOLS AND RESOURCES SUCH AS CAL-ADAPT. PG&E LOOKS FORWARD TO CONTINUING TO WORK WITH AND SUPPORT THE CEC AND OTHER STAKEHOLDERS IN THIS IMPORTANT UNDERTAKING."

PACIFIC GAS & ELECTRIC [194]

Integrate climate readiness into California's electricity system.

Integrating advanced technical understandings and models into electricity system realities requires that utilities, policy makers, regulators, and other stakeholders consider a number of additional knowledge gaps related to visualizations and tools, non-technical barriers such as institutional and legal structures, and interconnectedness of systems and operations related to the electricity sector.

In this area, ongoing work to enhance Cal-Adapt is already working with CAISO, the Energy Commission's Demand Analysis Office, and IOUs to visualize high-resolution climate projections and related (e.g., wildfire) scenarios in a manner that is useful to electricity sector stakeholders. A few tools leveraging existing projections are also under development, such as provision of heating demand days for a user-specified spatial region (IOU territory, census tract, etc.). Additionally, an ongoing study is investigating the Los Angeles area with regard to cascading impacts that begin with electricity sector disruptions and may extend to other vital sectors such as emergency response and public health. Finally, because climate resilience is a relatively new endeavor for which existing institutions, legal structures, and financing mechanisms have little prior application, research in this area is seeking to provide clear understandings of and solutions to non-technical barriers to the implementation of resilience options is an urgent area of inquiry.

Future research under initiative 7.2.3 would provide additional tools that IOUs, CAISO, the Energy Commission's Demand Analysis Office, and other electricity sector stakeholders to seamlessly integrate projections of additional climate parameters and probabilistic forecasts into their management, operations, and infrastructure-related decisions. For example, efforts that incorporate seasonal (e.g., CAISO's summer loads and resources assessment) or decadal (e.g., the Energy

194 http://docketpublic.energy.ca.gov/PublicDocuments/16-IEPR-01/TN214411_20161107T161611_Pacific_Gas__Electric_Comments_Pacific_Gas_and_Electric_Comment.pdf

Commission's demand forecast undertaken as part of the IEPR process) would benefit from use of seasonal and decadal climate projections that are currently under development. This is critical in recognition that historical climate no longer serves as an appropriate foundation for engineering and infrastructure-related decisions.

Table 50: Previous and Planned EPIC Investments on Increasing Resiliency of Electricity System

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Develop High-Resolution Climate Change Projections, Assess Risks, and Develop Resilience Options	Intra-urban Enhancements to Probabilistic Climate Forecasting for the Electric System (EPC-15-070) Probabilistic Seasonal and Decadal Forecasts for the Electricity System (EPC-15-036) Potential Impacts and Adaptation Options for the San Diego Area Electricity System (EPC-15-005) Modeling the Impact of Wildfires on California's Transmission and Distribution Grid (EPC-15-006) Climate Change in Los Angeles County: Grid Vulnerability to Extreme Heat (EPC-15-007) Aerosol impacts on the hydrology and hydropower generation in California (EPC-14-064) Improving Hydrological Snowpack Forecasting for Hydropower Generation Using Intelligent Information Systems (EPC-14-067) Monitoring the Urban Heat Island Effect and the Efficiency of Future Countermeasures (EPC-14-073)	Develop hybrid downscaling techniques for climate scenario modeling that combine the advantages of statistical and dynamic downscaling techniques (*GFO-16-306-2, agreement under development*) Real World Characterization of the Urban Heat Island Effect: Part II (*forthcoming GFO*)
Anticipating Interactions between Climate Change and Renewable Energy Systems	Carbon Balance with Renewable Energy: Effects of Solar Installations on Desert Soil Carbon Cycle (EPC-15-039) Understanding and Mitigating Barriers to Wind Energy Expansion in California (EPC-15-068)	No current or planned investments
Integrating Climate Readiness into the Electricity System	Visualizing Climate-Related Risks to the Electricity System using Cal-Adapt (EPC-15-008) Risk Modeling and Cognitive Science Characterization of Barriers to Climate Change Adaptation in California Electricity Sector (EPC-15-078) Electrical Grid Teleconnected and Cascading Climate Change Impacts in Los Angeles (EPC-15-080)	No current or planned investments

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

Initiatives in this area continue to advance our understanding of climate-electricity interactions—the foundation of which was developed in the first two investment periods—to address the rapidly evolving needs of electricity sector stakeholders. Specifically, initiatives in this area will respond to needs articulated by IOUs, CAISO, CPUC, and OPR through Technical Advisory Committees associated with ongoing EPIC-funded research as well as inter-agency working groups such as OPR's Technical Advisory Group on climate adaptation. These initiatives are also responsive to the Energy Commission's IEPR process as well as to gaps revealed by the U.S. DOE's Resilience Partnership, which has engaged several California utilities in concert with other utilities nationwide, in a process to develop initial vulnerability assessments and response plans.

As federal priorities appear to be changing, there is a pressing need for states like California to demonstrate leadership to strategically engage the energy sector in continued resilience efforts. The Energy Commission along with the CPUC has already begun the groundwork to promote resilience through the Energy Sector Adaptation Implementation Working Group. The Working Group will depend on further studies outlined below in order to lead with a rigorous scientific backing.

There are three main foci to the *EPIC 2018 – 2020 Investment Plan* under this sub-theme. First, EPIC funded research will advance the understanding of potential climate change impacts on the electricity sector as well as resilience options for operations and infrastructure-related decisions. Second, these initiatives will foster a transition to low-carbon electricity sources that is resilient to climate change by anticipating and planning for factors that affect renewable energy systems. Finally, recognizing that developing a technically advanced knowledge base is not sufficient to effect change, these initiatives will develop research-based tools and rigorously investigate system interconnectedness to provide a rigorous basis for directly and practically informing planning and operations.

Through the proposed initiatives, the Energy Commission looks forward to providing California's IOUs with a comprehensive knowledge base and set of tools to provide ratepayers with resilient, cost-effective electricity services.

Initiative 7.2.1 Improved Understanding of Climate- and Weather-Related Risks and Resilience Options

Description	Over the past two EPIC funding cycles as well as IEPR and Safeguarding California processes, the Energy Commission's engagement of utilities and CAISO in the research process has strengthened appreciably. Research in this area will respond directly to IOU requests for projections and probabilistic forecasts of hydrological and meteorological parameters that are needed for planning and operations. Development of those projections will build on ongoing, EPIC-funded development of a new methodology for improving climate projections for parameters of interest (e.g., Delta breeze, cloud cover) to

California's electricity system and for which the scientific basis was previously not available, as well as on development of probabilistic projections (ongoing) that can provide a basis for better seasonal and decadal planning. This area would also consider development of probabilistic forecasts for additional parameters (e.g., short-term precipitation forecasting) that could improve electricity sector operations. Research in this area will be closely coordinated with IOUs and CAISO to illuminate climate-related risk, potential impacts, and resilience options for the electricity sector as well as the DACs that IOUs serve. For example, development of a coastal evolution model to estimate shoreline changes in locations where important coastal energy resources and/or disadvantaged communities are located could enhance resilience planning for DACs as well as siting. Given that California's electricity system already must contend with many weather-related challenges, this area of investment will seek to produce "win-win" strategies, which offer benefits under current and highly variable climatic conditions as well as those anticipated in the future. For example, reducing negative impacts of urban heat effects could provide benefits under California's current climate, as well as substantial resilience to future climate. Development of strategies will be supported by analysis of projected as well as recent historical data.

EPIC supported research depends on observed historical weather and climate parameters. In the past, most of the data necessary to do this was collected by federal agencies. However, due to changes in priorities of the federal administration, the collection, storage, and dissemination of observational data may stop or be severely curtailed. California, via the EPIC program, may partially support the collection of data for parameters of importance for the energy system including snowpack conditions, stream flows, ambient temperature, precipitation levels, relative humidity, and solar radiation. EPIC may also support analyses of the data to detect trends that would indicate how the energy system should prepare for a changing climate.

Impact if Successful

Results of research funded through this initiative could be used to enable integration of projected and/or probabilistically forecast climate relevant parameters into all aspects of electricity sector planning, operations, and infrastructure investment. These climate projections and forecasts could also provide a foundation for identification of risks specific to disadvantaged communities as a starting point for developing solutions.

	Also, research results could be used to help ensure that California's electricity utilities and CAISO anticipate and are able to prepare for climate change with sufficient lead time that they are able to find ways to implement sound, cost-effective, practical resilience strategies. Results could also be used to enable integration of a cross-sectoral, multi-regional portfolio research for California's Fifth Climate Change Assessment; this integration is only possible if studies use consistent scenarios.
Primary Users and/or Beneficiaries	Primary beneficiaries would be ratepayers, businesses, and industry who rely on resilient electricity services. Primary users include the utilities and CAISO.
Metrics and/or Performance Indicators	Development of projected climate parameters requested by IOUs, CPUC, CAISO Use of projected climate scenarios and weather-related parameters by IOUs, CPUC, and other energy sector stakeholders Use of projected climate scenarios and weather-related parameters to promote climate resilience in disadvantaged communities Use of vulnerability assessments and/or resilience options by IOUs, CAISO and/or state agencies Use of vulnerability assessments and/or resilience options promote climate resilience in disadvantaged communities
Topic(s) addressed	High-resolution climate projections and vulnerability assessments for the electricity sector
Value Chain	Grid Operations/Market Design Generation Transmission/Distribution
Program Area(s)	Applied Research and Development

Initiative 7.2.2 Clarify Interactions between Renewable Electricity Systems and Climate Change to Ensure an Effective, Resilient Transition to Low-Carbon Energy in California

Description	To date, research on risks and resilience options for the electricity sector has focused primarily on existing systems and infrastructure. However, California's electricity system is undergoing rapid evolution, including ambitious and accelerating shift to renewable energy. This transition to a low-

	carbon grid must—if it is to be effective and resilient—anticipate and incorporate challenges and opportunities presented by a changing climate. Research in this area will clarify how climate change might affect renewable energy systems as well as how integrate these impacts into design, deployment, and operations. For example, wind resources are determined by atmospheric conditions that are in turn affected by climate change, which may have substantial impacts on the suitability of a given location for wind generation. California must anticipate climate-related changes to the availability and distribution of wind, and solar resources to ensure appropriate long-term investments in low-carbon energy systems. Research in sub-theme 7.1, “Identify Optimal Pathways for Achieving California’s Energy and Climate Goals”, will consider from a holistic perspective how to integrate these changes system-wide.
Impact if Successful	Research results could be used to ensure that policies, planning, and operations related to renewable energy account for the adaptation imperative, such that this mitigation strategy is truly coherent with—and successful in—a changing climate.
Primary Users and/or Beneficiaries	Primary beneficiaries include developers of long-term energy scenarios as well as those who use such scenarios to inform energy policy in California, ratepayers, businesses, and industry, all of whom rely on cost-effectively meeting California’s Renewable Portfolio Standard while maintaining reliable electricity services.
Metrics and Performance Indicators	Use of research results by state agencies involved with energy sector planning and regulation. Use of research results to identify and implement climate resilient strategies on the path to California’s energy goals (for example, RPS, Scoping Plan). Successful collaboration with IOUs and/or other electricity sector stakeholders in the research process. Use of research results by Cal-Adapt, Climate Console, and/or other tools that support energy sector resilience.
Topic(s) addressed	Climate-Ready Low-Carbon Grid
Value Chain	Generation
Program Area(s)	Applied Research and Development

Initiative 7.2.3 Integrate Climate Readiness into Electricity System Operations, Tools, and Models

Description

Integrating climate readiness into electricity system operations will require additional tools and models to bridge the gap between actionable science and new auxiliary products that support effective use of improved technical knowledge. To bridge this gap, this initiative will provide tools that feed directly into management, planning, and operations, including cost-benefit analyses of resilience investments. This initiative will help IOUs assess the costs, benefits, and viability of resilience measures as well as how to prioritize investments associated with different climate-related hazards. Another key element of this initiative will draw on research results from ongoing and planned EPIC-funded studies to build on the platform provided by Cal-Adapt, expanding it with vulnerability and resilience tools for DACs as well as custom tools for IOUs that leverage probabilistic forecasts at seasonal and decadal scales to inform utilities' operations and planning.

Additional tools may also be needed to integrate a clear understanding of the electricity system's interconnectedness with other areas (e.g., emergency response, public health, and interconnected infrastructure between sectors) into models. Considering interconnectedness is crucial to informing robust resilience strategies that contribute to the state's overall readiness, as articulated in the Energy Commission's 2016 IEPR Update. Decision support tools for example could prevent and respond to risks related to interconnected systems and infrastructure (for example, water and energy systems). Such tools would need to be tailored to the assets and challenges of sub-regions within California, while being cognizant of interconnected risks originating from more distant locations. Work being done in EPC 15-080 serves as a limited pilot study in translating these seemingly distant risks into local problem-solving technologies and decision support tools. But, because risks vary by geography, additional tools need to be developed that fit the needs and assets of energy systems as communities and IOUs plan for and attempt to respond to interconnected risks. For example, cross-cutting tools may include methods to integrate hydropower management across river basins and tools to improve upon and create new decision –support systems to coordinate hydropower operation to meet energy, flood control, and environmental goals. Limited efforts in these areas are ongoing and will

	contribute to the basis for understanding non-technical barriers and interconnectedness throughout IOU territories.
Impact if Successful	Results could be used to enable integration of best available scientific research on climate change into routine electricity sector planning, operations, and management Results could be used to enable integration of best available scientific research on climate change into electricity sector efforts to build climate readiness
Primary Users and/or Beneficiaries	Primary beneficiaries would be ratepayers, businesses, and industry who rely on resilient and affordable electricity services. Primary users would be all of the above plus utilities and CAISO.
Metrics and Performance Indicators	Successful collaboration with IOUs and/or other electricity sector stakeholders (particularly populations vulnerable to impacts of climate change) in the research process. Use of results as input for utility and local government decision-making related to climate readiness and electricity sector resilience.
Topic(s) addressed	Electricity sector resilience tools
Value Chain	Grid Operations/Market Design Generation Transmission/Distribution
Program Area(s)	Applied Research and Development

Table 51: Ratepayer Benefits Summary For Sub-Theme 7.2

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transpo rtation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 7.2.1 Improved Understanding of Climate- and Weather-Related Risks and Resilience Options	X	X		X	X			X	
Initiative 7.2.2 Clarify Interactions between Renewable Electricity Systems and Climate Change to Ensure an Effective, Resilient Transition to Low-Carbon Energy in California		X		X	X			X	
Initiative 7.2.3 Integrate Climate Readiness into Electricity System Operations, Tools, and Models	X	X		X	X			X	

Source: California Energy Commission

7.3 Evaluate Strategies to Mitigate the Impacts of the Electricity System on the Environment and Public Health and Safety

Even as California presses for cleaner sources and lower consumption of electricity to reduce GHG emissions, experience has shown that there can be unintended consequences on other aspects of the state's natural resources—its air, plants and animals, habitats, and ecosystems—and the health and safety of all Californians. Energy goals need to be met in an environmentally responsible manner that takes these factors into account.

With constant innovation in energy technologies and emerging resource areas for new deployment of renewable energy, regulators and other stakeholders are confronted with knowledge gaps about the potential environmental impacts. These uncertainties can make decision makers reluctant to approve new facilities and slow the acceptance of new technology by the public, investors, regulators, and other key stakeholders. Research to fill these knowledge gaps can lower the soft-costs of deployment, both for permitting and management requirements to avoid, minimize, or compensate for potential impacts on sensitive species (i.e., mitigation). California-specific science is needed to support landscape-level energy and environmental conservation planning. Determining which risks are relatively inconsequential would allow monitoring or mitigation to be focused where actually needed.

Emerging electricity technologies may have low environmental impacts during the generation or use phase, but the full life cycle impacts are often poorly understood. Often neglected are the resource extraction and end-of-life phases. For instance, some technologies utilize rare natural resources. This may not be an issue in the early stages of technology market penetration but could become more problematic when it reaches a level that could contribute to energy and climate goals. In some cases, impacts could be reduced by finding alternative materials. Electrification of sectors that are large polluters may be part of the solution, e.g., transportation.

The rapid pace of innovation can also create new safety hazards for energy workers and others. Examples include bi-directional flows on distribution circuits that may be hot when line workers need to perform maintenance or fire hazards for occupants and first responders from various types of energy storage devices located in homes and other buildings. The risks need to be evaluated and reduced to acceptable levels through R&D on technological, regulatory, or educational solutions.

Regulators, energy developers, and other stakeholders need information and tools to make decisions about deploying low-carbon electricity generation capacity in a manner that is environmentally responsible, safe for our Californians, and sensitive to the needs of disadvantaged communities. Topics include better understanding of risks and development of effective mitigation tools and strategies for sensitive species and habitats, indoor environmental quality and associated health risks, public health and safety, and material supply and disposal for electricity components.

Energy Commission research has made significant headway in determining the level of risk to populations of various sensitive species from the electricity system and ways to mitigate those risks. Research has helped energy developers and planners site new energy projects in locations with low conflict with species to avoid impacts and associated soft costs. It provides risk information to regulators and permitting agencies, and expands the suite of effective mitigation tools and strategies to minimize or compensate for impacts. Some of these tools show promise for advancing from applied research to market or widespread adoption by stakeholders. The Energy Commission works with federal partners and other western states in identifying research needs and sharing research results.[195]

KEY TECHNICAL AND MARKET CHALLENGES

Despite the advancements described above, each new energy technology or geographic energy resource area presents new environmental challenges, or at the very least, new knowledge gaps. One of the challenges for the EPIC research agenda is to be responsive to emerging issues that create barriers to deployment of low-carbon energy technology while also being proactive to anticipate such questions and have sound scientific answers ready for decision makers in government, industry, and communities. It is unclear whether federal funding for studying renewable energy-wildlife interactions and other environmental questions will continue at the past rate.

Find environmental and land use solutions to facilitate the transition to a decarbonized electricity system

The boom in renewable generation has brought with it new and different environmental impacts than the conventional generation resources built in the past. The footprint acreage associated with renewable projects is much larger than for conventional natural gas plants. In addition, remote renewable resources have different impacts than traditional power plants, such as on biological resources and competing land uses, particularly in desert, farmland, and, perhaps in the future, offshore environments. The California Intergovernmental Renewable Energy Task Force was recently established to begin marine spatial planning for future renewable wind and wave energy development opportunities in the Outer Continental Shelf along the Golden State. This effort is likely to identify important knowledge gaps about the interactions of energy facilities and marine wildlife.

Enhance human health and safety associated with the electricity sector

Public health and safety are core benefits sought by the CPUC from EPIC research. The emergence of new low carbon energy technologies can create new health or safety hazards for on-site energy workers, neighbors, and first responders to public safety incidents. Some measures to improve building energy efficiency may negatively affect indoor air quality, and hence the health of the occupants. For instance, sealing the building envelope to increase energy efficiency can also retain indoor pollutants without proper ventilation, including CO_2 that may reduce cognitive performance. One current EPIC project is developing a research roadmap to identify and prioritize the research needs regarding public health risks. Research is needed to evaluate these risks and reduce them to acceptable levels through R&D on technological, regulatory, or training solutions. Conversely, there can be benefits in indoor environmental quality from retrofitting existing buildings that could motivate occupants to adopt these energy

195 Such as through the Multiagency Avian-Solar Collaborative Working Group and its Avian-Solar Science Coordination Plan

efficiency technologies. A comprehensive evaluation of the potential benefits has not been conducted.

Improve overall environmental performance in the entire supply chain for the electricity system

When making energy policy or procurement decisions, it is essential to identify potential environmental consequences over the full life cycle (from extracting natural resources for manufacturing devices to final disposal at the end of their lives) for a comprehensive set of environmental factors, not just global warming potential, to understand the trade-offs involved. Energy technologies that have small environmental footprints during the electricity generation or storage phases may have large impacts in the resource production or end-of-life phases, such as disposal of batteries or solar PV panels. This can be especially true when scaling up to levels needed to meet California's GHG reduction and renewable energy goals. The effects can be further complicated by behavioral responses of end-users, including how rapidly a technology gets adopted. Research is needed to determine factors to consider in life cycle assessments of new industrial processes for emerging energy technologies. Options for materials or disposal processes are needed that are more benign to the environment and health and safety.

Table 52: Previous and Planned EPIC Investments on Mitigating Impacts of the Electricity System on the Environment and Public Health and Safety

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Sensitive Species and Habitats	Learning from Real-World Experience to Understand Renewable Energy Impacts to Wildlife (EPC-14-061) Rotor-Mounted Bat Impact Deterrence System Design and Testing (EPC-14-071) Distributed Generation Environmental Planner (EPC-15-029) Assessing California's Mitigation Guidelines for Burrowing Owls Impacted by Renewable Energy (EPC-15-040) Development of a Genoscape Framework for Assessing Population-Level Impacts of Renewable Energy Development on Migratory Bird Species in California (EPC-15-043) Optimizing Solar Facility Configuration Effects on Habitat, Managed Plants, and Essential Species Interactions (EPC-15-060)	Investigating the Impacts of "Lake Effect" from Solar Energy-Generating Facilities on Avian Behavior (pending Q2, 2017) Use of Indoor Rearing for Head-Starting Desert Tortoises (EPC-16-038, pending Q2, 2017) Habitat Influences on Desert Tortoise Translocation Success (pending Q2, 2017)
Air Quality, Public Health, and Safety	Emerging Energy Public Health Research Roadmap (EPC-15-034) Ventilation Solutions for Energy Efficient California Schools: Improving Indoor Air Quality through Advanced, High Performance HVAC (EPC-15-033) Smart Ventilation for Advanced California Homes (EPC-15-037)	Assessing Cooling Tower PM2.5 and PM10 Emissions using Advanced Instrumentation, Plume Transects, and Plume Modeling (pending Q2, 2017)
Environmentally-Friendly Material Supply and Disposal	No projects	Benefits and Challenges in Deployment of Low GWP A3 Refrigerants in Residential and Commercial Cooling Equipment (pending Q2, 2017) A Life Cycle Assessment of the Environmental and Human Health Impacts of Emerging Energy Storage Technology Deployment (EPC-16-039, pending Q2, 2017)

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

The Energy Commission's initiatives will focus on improving the environmental, health, and safety performance of the electricity system to enable the achievement of California's energy and GHG reduction goals. Better environmental, health, and safety performance is also expected to reduce soft costs of renewable energy, indirect societal costs, and barriers to deployment of low-carbon energy technology. The initiatives may solicit both applied research to investigate emerging issues and market facilitation to advance the "technology readiness" of previous prototype tools and strategies into common practice.

Initiative 7.3.1 Find Environmental and Land Use Solutions to Facilitate the Transition to a Decarbonized Electricity System

Description

This initiative will fund research to find solutions to potential environmental issues in deployment of renewable energy such as the costs to developers (and ultimately to ratepayers) of long permitting delays and post-construction monitoring and mitigation. The evolution of clean energy technologies, expansion into new energy resource areas, and climate change are likely to reveal knowledge gaps that will be a major focus of this initiative.

Research topics will investigate risks to sensitive species and habitats from their interactions with energy facilities, and particularly to discover the mechanisms involved so that effective solutions can be developed. For example, one emerging area is for offshore wind on California's Outer Continental Shelf; this initiative may conduct marine environmental research to assist the development, planning, and permitting of emerging wind and wave energy generation in response to the actionable information needs of the California Intergovernmental Renewable Energy Task Force. Specific topics of interest might include distribution and risk to marine mammals, birds and bats, and atmospheric and oceanic effects of large-scale offshore wind development (e.g., coastal fog and waves).

While current research is examining whether birds are fatally attracted to solar energy facilities (the "lake effect"), this initiative could determine the mechanism of this attraction. In some cases, the search for mechanisms may require looking beyond conventional single-species studies to determine how renewable energy facilities influence complex ecosystem interactions on which species depend.

This initiative will also develop innovative avoidance, impact minimization, or compensatory mitigation tools or strategies

	for sensitive species known or discovered to be at greatest risk from renewable energy development or with the greatest opportunity to reduce energy costs. For example, novel deterrence systems may be developed and evaluated to reduce wildlife fatalities at renewable energy facilities such as reducing the lake effect. Some tools or strategies may have already been proven in initial prototype studies but need support to be advanced toward a commercial readiness level or further developed for widespread use beyond the case study site. As renewable energy generation encroaches on farmland, planners and developers face resistance about changing traditional land uses. The initiative may explore opportunities for co-uses of and co-benefits from the land, including ecosystem services as ways to increase the compatibility and public acceptance of renewable energy development.
Impact if Successful	This initiative could support the achievement of the state's energy and GHG reduction goals in several ways. First, the initiative could provide timely, best available science about potential impacts of renewables on species and habitats in support of landscape-level planning in new regions. Second, permitting is expected to become more expedited if proven mitigation methods are available to minimize impacts. Research may also determine which potential risks are actually insignificant and can be "retired" from further consideration in permitting, monitoring, and mitigation, thereby reducing soft costs and developer uncertainty. Those changes could be sufficient to make additional energy resource areas commercially viable. Some R&D mitigation tools have the potential to become commercially successful, creating California jobs and economic benefits.
Primary Users and/or Beneficiaries	The primary direct users of the research findings would be permitting and regulatory agencies. This would also benefit energy developers with greater certainty and assistance in siting projects and other stakeholders such as environmental groups. Developers of mitigation tools may also benefit from proving their concepts or advancing them toward commercialization that in some cases could have global markets.
Metrics and/or Performance Indicators	User adoption of market-ready decision support tools that were previously prototyped (e.g., DG Environmental Planner, Desert Tortoise Spatial Decision Support System)

- User adoption of market-ready mitigation technologies that were previously prototyped (e.g., bat impact deterrent system)

Topics addressed	Improve understanding of the risks from interactions between energy facilities and species and their habitats, develop or advance tools and strategies to avoid, minimize, or compensate for impacts
Value Chain	Generation Transmission Distribution
Program Area(s)	Applied Research and Development Market Facilitation

Initiative 7.3.2 Enhance Human Health and Safety Associated with the Electricity Sector

Description

The forthcoming public health research roadmap, being developed with support from the first investment plan, will identify research priorities for this initiative. This initiative will fund research to support studies of human exposure to emerging energy-related health threats (such as indoor pollutants), quantification of the risks, and where significant, of finding solutions to reduce risks to an acceptable level. Research topics include addressing public health concerns associated with indoor air quality. Some technologies to improve indoor air quality (e.g., smart ventilation and measurement technology) that have been proven in pilot stages may be ready for demonstration of their technology readiness.

Research will quantify risks associated with emerging electricity sector technologies, emphasizing health risks in environmental justice/disadvantaged communities. Approaches will be developed to reduce these risks. These may include potential public health hazards associated with fast ramping from black start and human health and safety risks from new electrical devices and how to reduce any risks.

Research topics will also investigate potential health and safety benefits of energy strategies. For example, the initiative may produce tools to strategically site energy storage to reduce air pollution and associated health risks generated by fossil fuel peaker power plants, particularly in disadvantaged communities. Energy performance and indoor air quality of passive (using ambient energy sources such as daylighting, natural ventilation, and solar energy) versus active (using purchased energy such as HVAC and electric lights) ZNE building designs may be compared. This initiative could also evaluate how energy efficiency technologies and standards would affect indoor environmental quality benefits (or disbenefits) and human well-being. A third area of potential research in this topic would be to develop training and equipment to reduce risks for workers, such as for fire and code officials and inspectors to safely and effectively respond to incidents involving the emerging electricity system, e.g., solar power energy systems, storage, microgrids.

A fourth area of potential research is evaluating the environmental impacts, associated with early transitioning to low global warming refrigerants, such as transcritical CO_2, propane and others, and impacts across multiple climate zones, including building and industrial sectors.

Impact if Successful	This initiative will identify and quantify health risks before they become public health crises. Some mitigation tools could become commercially successful. Quantifying indoor environmental quality benefits associated with ZNE retrofits for existing buildings could motivate more rapid adoption of the efficiency technologies by the owners. The initiative may also create a better-trained and equipped workforce that would be less susceptible to illness or injury.
Primary Users and/or Beneficiaries	The primary direct users of the research findings would be the building standards office of the Energy Commission, the CPUC, and the California Department of Public Health. It would also benefit disadvantaged communities. Developers of mitigation tools may also benefit from proving their concepts or advancing them toward commercialization.
Metrics and Performance Indicators	• Projections of improvements in Disability Adjusted Life Years (DALYs) linked to clean generation, storage, etc. • Reduction in exposure to pollutants linked to health conditions relative to conventional technologies • Decreased rate of injuries from safety incidents involving clean energy technologies
Topic(s) addressed:	Indoor air quality and public health; public health and safety
Value Chain:	Generation Distribution Demand-Side Management
Program Area(s):	Applied Research and Development Technology Development and Demonstration Market Facilitation

Initiative 7.3.3 Improve Lifecycle Environmental Performance in the Entire Supply Chain for the Electricity System

Description	This initiative will focus on finding substitute materials or processes (e.g., extracting natural resources to make devices and final disposal methods) that have the great potential to reduce emissions of global warming pollutants or other environmental impacts of energy technologies. For example, the initiative may fund research to search for substitutes for materials with high global warming potential, toxic chemicals that have less significant environmental impacts than conventional materials such as aluminum foil used in lithium ion batteries. Improved recycling or reuse methods may be developed and tested with smaller environmental impacts, e.g., to recycle toxic by-products, such as from polysilicon production for PV panels, or to reuse materials from damaged energy storage systems. Projects may assess the life-cycle environmental impacts of additional emerging energy technologies for efficiency, generation, storage, and transmission, such as disposal and recycling options, particularly for PV panels and batteries. Additionally, the initiative may investigate behavioral dimensions such as adoption rates, use patterns, rebound effects, and context of adoption.
Impact if Successful	This initiative could help reduce California's GHG emissions while also reducing other environmental burdens and their impacts associated with the materials used in energy technologies or the industrial processes used throughout their life cycles, especially disposal or retirement. If these potential solutions can be made cost-effective, they could become marketable here and elsewhere or open up new value propositions.
Primary Users and/or Beneficiaries	Policymakers could benefit by understanding lifecycle impacts associated with various technologies and develop policies to mitigate impacts for clean energy technologies. Ratepayers would all benefit from a healthier environment. Entrepreneurs may benefit from new market opportunities for less toxic materials or for technology disposal processes.
Metrics and Performance Indicators	Commonly used life cycle impact categories such as: global warming, stratospheric ozone depletion, acidification, eutrophication, photochemical smog, terrestrial toxicity, aquatic toxicity, human health, resource depletion, land use, and water use

Topic(s) Addressed	Environmentally-friendly materials Environmentally-friendly disposal options
Value Chain	Grid Operations/Market Design Generation Transmission/Distribution Demand-side Management
Program Area(s)	Applied Research and Development Market Facilitation

Table 53: Ratepayer Benefits Summary For Sub-Theme 7.3

Initiative	**Promote Greater Reliability**	**Lower Cost**	**Increased Safety**	**Societal Benefits**	**GHG Emissions Mitigation and Adaptation**	**Lower Emission Vehicles/Transportation**	**Economic Development**	**Public Utilities Code 740.1**	**Public Utilities Code 8360**
Initiative 7.3.1 Find Environmental and Land Use Solutions to Facilitate the Transition to a Decarbonized Electricity System	X	X		X	X			X	
Initiative 7.3.2 Enhance Human Health and Safety Associated with the Electricity Sector			X	X				X	
Initiative 7.3.3 Improve Lifecycle Environmental Performance in the Entire Supply Chain for the Electricity System		X		X	X			X	

Source: California Energy Commission

CHAPTER 9
Theme 8: Catalyze Clean Energy Investment in California's Disadvantaged Communities

California's leaders have made clean energy equity a state priority. The Clean Energy and Pollution Reduction Act (de Leon, SB 350) directed the Energy Commission to identify some of most critical barriers for low-income energy customers accessing clean energy opportunities across the state. The Energy Commission's *Low-Income Barriers Study*, adopted in December 2016, identified specific challenges unique to disadvantaged communities including low home ownership rates, grid access for remote or underserved communities, and insufficient access to capital.

"CAL EPA HAS DESIGNATED DISADVANTAGED COMMUNITIES AS THOSE THAT SCORED AT OR ABOVE THE 75TH PERCENTILE USING CALENVIROSCREEN"
CALIFORNIA ENERGY COMMISSION, *LOW-INCOME BARRIERS STUDY*[196]

The study also provided recommendations intended to have a transformative effect on access to clean energy investments for low-income customers and local small businesses in disadvantaged communities. This includes a recommendation that the Energy Commission target 25 percent of technology demonstration and deployment funding for sites located in disadvantaged communities.

In addition to the *Low-Income Barriers Study,* the Energy Commission held public workshops in Fresno and Los Angeles on March 20th and March 27th respectively to further identify gaps in this area and identify the most beneficial role EPIC can play in helping address clean energy equity barriers. This chapter describes funding initiatives for strategic clean energy investments into disadvantaged communities. These efforts seek to:

Develop data-driven tools for energy projects targeting disadvantaged communities

Data-driven tools have the potential to significantly improve the efficacy and efficiency of clean energy projects targeting low-income customers and disadvantaged communities. Furthermore, these tools can potentially inform policy designs to open new market opportunities incentivizing clean energy investment in disadvantaged communities.

196 Scavo, Jordan, Suzanne Korosec, Esteban Guerrero, Bill Pennington, and Pamela Doughman. 2016. Low-Income Barriers Study, Part A: Overcoming Barriers to Energy Efficiency and Renewables for Low-income customers and Small Business Contracting Opportunities in Disadvantaged Communities. California Energy Commission. Publication Number: CEC-300-2016-009-CMF.

“[SOME] BARRIERS STEM FROM POLICY AND PROGRAM DECISIONS, AND THESE MAY BE OVERCOME THROUGH NEW POLICY DEVELOPMENT OR PROGRAM REFINEMENT.”

CALIFORNIA ENERGY COMMISSION, *LOW-INCOME BARRIERS STUDY*[197]

Scale-up emerging technology solutions best suited to the needs of disadvantaged communities

The Energy Commission, under the previous two EPIC Investment Plans, has taken steps to ensure EPIC investments include targeted benefits to disadvantaged communities, including funding a number of demonstration projects located in disadvantaged communities. These projects provide direct benefits to local communities and serve as important case studies for future market deployment and energy policy and program design.

197 Ibid.

8.1 Advance Innovations in Big Data to Accelerate Clean Energy Equity

The clean energy markets for low-income and disadvantaged communities have grown slowly. The Clean Energy Group identified that solar markets have opened to low-income customers only recently, with penetration still lagging significantly behind other customer groups.[198] California currently has several major energy-related programs that provide support to low-income customers and disadvantaged communities. In addition, policymakers are exploring new market-driven strategies that could potentially incentivize the deployment of distributed energy resources in disadvantaged communities.

The Energy Commission's Low-Income Barriers Study identified several policy and program barriers limiting access to clean energy for low-income customers and disadvantaged communities. Many of these barriers are the result of current limitations in existing analytical tools used to plan, implement, and refine policies and programs targeting clean energy investments in disadvantaged communities including:

Improve energy data granularity to target investments and maximize impacts

Efforts like the California Environmental Protection Agency's CalEnviroScreen have provided a tool to help program administrators target investments to disadvantaged communities. However, even tools like CalEnviroScreen lack the granularity needed to target investments to specific locations or customer segments that would reap the greatest benefits.

Examples of increased granularity include information on building age, envelope characteristics, appliances installed, and occupancy and energy usage patterns at a block or neighborhood level.

For example, at the April 11, 2017 workshop on "Customers of Climate Science Data," APEN recommended EPIC provide support for community-based projects to use climate scenarios in Cal-Adapt, collect data on local conditions, and identify improvements needed to strengthen neighborhood resiliency, with particular outreach efforts for linguistically isolated communities.

Leverage environmental, safety, and reliability datasets and analytical tools to increase non-energy and energy benefits for disadvantaged communities

Non-energy benefits, such as air pollution reduction, safety, and reliability, are important drivers for clean energy technology deployment in disadvantaged communities. In most cases, these data systems are not linked. Being able to link these various data systems can lead to more programmatic actions that optimize the benefits of clean energy investments for multiple purposes.

"A FULLER ACCOUNTING OF NON-ENERGY BENEFITS COULD BE NECESSARY, ESPECIALLY GIVEN THE MULITFACETED NEEDS THAT LOW-INCOME ENERGY RETROFIT PROGRAM ARE INTENDED TO ADDRESS"
CALIFORNIA ENERGY COMMISSION
LOW-INCOME BARRIERS STUDY[199]

198 Milford, Lew, and. Robert Sanders. 2017. A Resilient Power Capital Scan: How Foundations Could Use Grants and Investments to Advance Solar and Storage in Low-Income Communities. Clean Energy Group.

199 Scavo, Jordan, Suzanne Korosec, Esteban Guerrero, Bill Pennington, and Pamela Doughman. 2016. Low-

Translate data science into actionable energy-related strategies to inform project design and decision-making

For policymakers and practitioners, too much data can be just as challenging as not enough data. New tools and other efforts are needed that can provide information to decision-makers at the right time and in the right format. Furthermore, these tools can help improve collaboration among different stakeholder groups and streamline the process for moving high-level conceptual discussions into the project implementation phases.

Income Barriers Study, Part A: Overcoming Barriers to Energy Efficiency and Renewables for Low-income customers and Small Business Contracting Opportunities in Disadvantaged Communities. California Energy Commission. Publication Number: CEC-300-2016-009-CMF.

Table 54: Previous and Planned Investments on Accelerating Clean Energy Equity

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Market Assessment	Connecting Emerging Energy Technologies and Strategies to Market Needs and Opportunities (300-15-009)	Connecting Emerging Energy Technologies and Strategies to Market Needs and Opportunities (300-15-009)

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

The Energy Commission will advance initiatives to collect and analyze information on the clean energy markets for low-income and disadvantaged communities. These efforts will facilitate more strategic policy interventions to cultivate markets to ensure more equitable access to the benefits of clean energy in California.

Initiative 8.1.1 Advancing the Information Infrastructure for California's Low-Income and Disadvantaged Communities

Description

This initiative will support continued public data and information collection and case study development, as well as increase local, regional, and state analytical capacity to determine the most pressing market gaps for clean energy in low-income and disadvantaged communities. Data collection and case study development will focus on increasing deployment of DERs in these communities, including energy-efficiency technologies and practices, demand response tools, on-site renewable generation, on-site energy storage and electric vehicles.

Greater analytic capacity and community engagement is needed to assess typical energy-use patterns, utility costs, and the energy-related quality of life for communities with and without clean energy community measures, and determine what non-energy benefits clean energy technology packages can provide. The analysis from this initiative will identify replicable high-impact clean energy design packages for low-income and disadvantaged communities.

Impact if Successful

Energy data collection, policy research, and economic analysis funded by this initiative will support strategic investments by EPIC and others and help channel resources to areas most in need.

Primary Users and/or Beneficiaries	Policy makers at local, regional, and state levels, property owners, and developers; community organizations, financiers, clean energy community project designers, and residents
Metrics and/or Performance Indicators	Increased clean energy investments in low-income and disadvantaged communities, number of technology and design packages replicated,
Topic(s) addressed	Clean energy community solutions Low-income communities Disadvantaged communities
Value Chain	Demand-Side Management
Program Area(s)	Applied Research and Development Market Facilitation

Table 55: Ratepayer Benefits Summary For Sub-Theme 8.1

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 8.1.1 Advancing the Information Infrastructure for California's Low-Income And Disadvantaged Communities		X		X	X			X	X

Source: California Energy Commission

8.2 Demonstrate Emerging Clean Energy Technology Solutions in Disadvantaged Communities

As mentioned previously, the Energy Commission Low-Income Barriers Study recommends that a minimum of 25 percent of Technology Demonstration and Deployment funds be directed to projects located in a disadvantaged community. These projects are important for several reasons including providing direct tangible benefits to disadvantaged communities. Equally important, they serve as critical case studies that can inform the design and implementation of California's energy-related programs supporting low-income customers and disadvantaged communities and help address the following:

Demonstrate performance of emerging energy technologies to facilitate uptake in programs serving disadvantaged communities

California has several major energy-related programs providing financial support to disadvantaged communities. Program administrators and implementers are hesitant to incorporate unproven new energy technologies into their programs and project portfolios despite the potential upside over current energy technologies. Demonstration projects can alleviate these concerns by providing important performance data on how emerging technologies will work in real-world conditions and how they will be received by the customers and communities being served.

"INCREASING EQUITABLE ACCESS…REQUIRES NUANCE AND UNDERSTANDING TO THE DIFFERING CHALLENGES FACING LOW-INCOME PERONS AND DISADVANTAGED COMMUNITIES"

CALIFORNIA ENERGY COMMISSION, *LOW-INCOME BARRIERS STUDY*[200]

Validate clean energy technologies' non-energy benefits to disadvantaged communities

"Non-energy benefits are often not considered in cost-effectiveness tests, which devalue some of the most important factors that motivate investment in clean energy upgrades."[201] Demonstration projects can fill information gaps on specific non-energy benefits of emerging clean energy technologies for disadvantaged communities. This information can help target further investments where they bring the highest social and public health benefits.

Lower soft costs for deploying clean energy technologies in disadvantaged communities

"Expanding access to energy efficiency for low-income customers requires market segmentation to address the differing needs and circumstances of renters, owners, and building owners." Demonstration projects can help test and validate potential models

200 Scavo, Jordan, Suzanne Korosec, Esteban Guerrero, Bill Pennington, and Pamela Doughman. 2016. Low-Income Barriers Study, Part A: Overcoming Barriers to Energy Efficiency and Renewables for Low-income customers and Small Business Contracting Opportunities in Disadvantaged Communities. California Energy Commission. Publication Number: CEC-300-2016-009-CMF.

201 Ibid.

for deploying emerging energy technologies in key market segments. Lessons learned and best practices resulting from these projects will help create templates for more effective and efficient outreach, delivery and installation of emerging energy technologies in disadvantaged communities. This includes identifying the most effective technology packages for specific market segments and providing locally visible demonstration sites to increase community familiarity with new energy technologies.

Table 56: Previous and Planned EPIC Investments on Demonstrating Technologies in Disadvantaged Communities

Topics	2012-14 Investment Plan	2015-17 Investment Plan
Community-Scale Development	Renewable Microgrid for a Medical Center (EPC-14-080)	Demonstration of Affordable, Comfortable, Grid Integrated Zero Net Energy Communities (EPC-15-094) Phase II of the EPIC Challenge (Anticipated 2018)
Zero Net Energy Retrofits	Zero Energy Residential Optimization - Community Achievement (EPC-14-042) Unlocking Industrial Energy Efficiency Through Optimized Energy Management Systems (EPC-14-075) Intelligent HVAC Controls for Low Income Households: A Low Cost Non-connected Device that Understands Consumer Preferences and Performs Adaptive Optimization (EPC-15-020) Ventilation Solutions for Energy Efficient California Schools: Improving Indoor Air Quality through Advanced, High Performance HVAC (EPC-15-033) Customer Centric Approach To Scaling Integrated Demand Side Management Retrofits (EPC-15-053) Innovate Net Zero: First ZNE Demonstration in Existing Low-Income Mixed-Use Housing (EPC-15-064)	Measure Results from Affordable Zero Net Energy Homes (EPC-16-001)
Water-Energy Nexus	Community Scale Digester with Advanced Interconnection to the Electrical Grid (EPC-14-052) Demonstration of Forward Osmosis to Produce Juice Concentrate, Purify and Reuse Wastewater and Reduce Energy Use (EPC-14-065) Wexus Energy and Water Management Mobile Software for the Agricultural Industry (EPC-14-070) Raw Wastewater Filtration to Increase Organic Removal Efficiency and Achieve Significant Electrical Savings (EPC-14-076) Irrigation Optimization and Well Pump Monitoring to Reduce Energy and Water Consumption (EPC-14-081) Advanced Renewable Energy Storage and Recycled Water Project (EPC-15-079) Biofiltration as an Advanced Primary Treatment Method to Achieve Substantial Energy Savings (EPC-15-088) Low Energy Biofiltration System with Low Backwash Rate for Groundwater Contaminant Removal (EPC-15-092)	Biological Double-Efficiency Process as an Advanced Wastewater Treatment Method to Achieve Substantial Energy and Water Savings (EPC-16-018)

Bioenergy	West Star North Dairy Biogas-to-Electricity Project (EPC-14-029) Enabling Anaerobic Digestion Deployment for Municipal Solid Waste-to-Energy (EPC-14-044) Energy Efficiency in California's Water Sector Using Customized Energy Management and Supervisory Control and Data Acquisition Systems (EPC-14-062)	No current or planned investments

Source: California Energy Commission

2018-2020 FUNDING INITIATIVES

The Energy Commission's initiatives will build off ongoing projects currently being conducted in disadvantaged communities. Energy Commission will use CalEnviroScreen to determine eligible project locations within IOU services territories. One of the key themes heard from stakeholders at the March 20th and 27th workshops was the need to have community based organizations actively involved in a the project to ensure it has the buy-in of the community and it best meets the community's needs. Going forward, the Energy Commission will evaluate how to best incorporate these and other considerations into solicitations targeting demonstration projects in disadvantaged communities.

Initiative 8.2.1 Investments for Energy Resilient Neighborhoods in Low-Income and Disadvantaged Communities

Description	This initiative will provide funding for demonstration and deployment of demand-side management projects in disadvantaged communities. The scope of projects will be based off initiatives described in the earlier chapters of this report, specifically those best suited to meet the needs of the residents in disadvantaged communities as well as the businesses and institutions that serve them. Specific attention will be on technology solutions for low-income multi-family housing, retrofits of existing buildings, rural low-income housing, and technologies that can ensure reliability for critical services and facilities serving low-income customers and small businesses located in disadvantaged communities.
Impact if Successful	These projects will provide direct benefits to the communities the projects are located in. In addition, these projects will benefit disadvantaged communities throughout IOU service territories by providing lessons learned and best practices industry partners and project developers can use to streamline the deployment of emerging energy technology solutions for specific residential market segments. In addition, these projects will provide critical information that can be used in the design and implementation of policies and programs targeting disadvantaged communities.

Primary Users and/or Beneficiaries	Community residents, community organizations, local governments, California utilities, manufactured home owners and producers, developers, and financiers.
Metrics and/or Performance Indicators	Number of identified ZNE, or near ZNE, clean energy design packages determined to be optimal for existing buildings in low-income and disadvantaged communities at the building and community scales.
Topic(s) addressed	Energy efficiency retrofits Disadvantaged communities Low –income communities Zero Net Energy Near Zero Net Energy Manufactured Home Communities
Value Chain	Demand-Side Management
Program Area(s)	Technology Deployment and Demonstration

Table 57: Ratepayer Benefits Summary For Sub-Theme 8.2

Initiative	Promote Greater Reliability	Lower Cost	Increased Safety	Societal Benefits	GHG Emissions Mitigation and Adaptation	Lower Emission Vehicles/Transportation	Economic Development	Public Utilities Code 740.1	Public Utilities Code 8360
Initiative 8.2.1 Building California's Resilient Neighborhoods in Low-Income and Disadvantaged Communities	X	X	X	X	X	X	X	X	X

Source: California Energy Commission

CHAPTER 10: EPIC Program Administration

This chapter discusses the procedures and processes the Energy Commission will follow for selecting, funding and managing projects and programs, and conducting program outreach efforts.

Stakeholder Participation

Investment Plan Development

The Energy Commission held a stakeholder workshop in Sacramento, CA on February 3, 2017 to gather stakeholder input on the proposed investments before developing the *EPIC 2018-2020 Investment Plan*. The Energy Commission released a draft of all proposed research initiatives on March 10, 2017. The EPIC administrators held three joint workshops on March 9 and March 14, 2017 in Northern California and March 24, 2017 in Southern California to provide an overview and solicit public comment on each of the administrators' draft Investment Plans. The Energy Commission also held five topical workshops that feed into Investment Plan development: Distributed Energy Resources Scoping Workshop on March 13, 2017 in Sacramento, Potential Areas of Research on Climate Change for the Electricity and Natural Gas Systems on March 16, 2017 in Sacramento, Incorporating Community Focused Equity in Research Funding on March 20, 2017 in Fresno and on March 27, 2017 in Los Angeles, and Customers of Climate Science Research on April 11, 2017 in Sacramento. The Energy Commission released the draft *EPIC 2018-2020 Investment Plan* on April 17, 2017, which allowed for an additional public comment period prior to consideration of the plan for adoption at the Business Meeting on April 27, 2017. Public comments received from these workshops are summarized in the appendices.

The Energy Commission has created a website (http://energy.ca.gov/research/epic/) that provides information and activities associated with EPIC funding, including information on past workshops, public comments, upcoming events, how to sign up for the list serve, and the latest documents associated with the program. The website also lists all active and closed solicitations, all the documents needed to submit a proposal, and notices of proposed awards for all solicitations.

Investment Plan Implementation

Energy Commission staff will hold public meetings for any interested individuals or entities (stakeholders) to provide input on implementing the *2018-2020 EPIC Investment Plan*, including input to identify synergy with other projects, solicit end-user needs and path to market opportunities, and facilitate a faster and more effective sharing of program results. These informal stakeholder meetings will not create a formal decision-making body and will work within the decision framework of the CPUC. They will serve to provide transparency and accountability for investments, coordinate research to avoid duplication, seek opportunities to leverage funds, and ensure research is targeting ratepayer benefits.

As required by CPUC Decision 12-05-037, the Energy Commission will consult with interested stakeholders no less than twice a year, both during the development of each investment plan and during its execution. The following types of stakeholders will be consulted, at a minimum:

- Members of the Legislature, to the extent their participation is not incompatible with their legislative positions
- Government, including state and local agency representatives
- Utilities
- Investors in energy technologies
- California Independent System Operator (California ISO)
- Consumer groups
- Environmental organizations
- Agricultural organizations
- Academics
- Business community
- Energy efficiency community
- Clean energy industry and/or associations
- Other industry associations

The Energy Commission will invite members of the public to participate in these meetings.

Senate Bill 350 (De León, Chapter 547, Statutes of 2015) prioritizes maximizing benefits to low-income customers and those in disadvantaged communities, as well as manufacturing and installing clean energy and pollution reduction technologies that create employment opportunities, including high-wage, highly skilled employment opportunities, and increased investment in the state. Since 2014, the Energy Commission has awarded 50 EPIC projects that have either headquarters or a project demonstration site in a disadvantaged community. In 2016, the Energy Commission committed to targeting 25 percent of technology demonstration and deployment funding for sites located in disadvantaged communities. While the initiatives outlined in Theme 8: *Catalyze Clean Energy Investment in California's Disadvantaged Communities*, focus on disadvantaged communities, opportunities exist throughout all program areas and are explicitly called out in many initiatives in this Investment Plan.

On October 8, 2015, Governor Brown signed Assembly Bill 865 (Alejo, Chapter 583, Statutes of 2015), which directs the Energy Commission to establish a diversity task force to consider and make recommendations about diversity in the energy industry. These efforts build upon the outline Energy Commission Chair Robert B. Weisenmiller submitted in a letter to the CPUC in November 2013.[202] In his letter, Chair Weisenmiller committed to increasing the participation of businesses owned by women, minorities, and disabled veterans through undertaking a comprehensive outreach plan to ensure that a diverse range of potential applicants know about, and understand how to participate in, EPIC Program activities, especially solicitations for projects.

Annual Reporting Requirements

The Energy Commission will submit annual reports to the CPUC in February of each year beginning in 2013. As articulated in the CPUC Phase 2 decision, annual reports will provide a program status update, including all successful and unsuccessful applications for EPIC funding awarded during the previous year.

In addition, Senate Bill 96 (statutes of 2013) added section 25711.5 to the California Public Resources Code. Regarding annual reports, Public Resources Code section 25711.5 requires the Energy Commission to

202 Letter to CPUC President Michael Peevey from California Energy Commission Chair Robert Weisenmiller, http://www.energy.ca.gov/research/epic/documents/2013-11-07_Letter_from_the_Chair_re_AB_340-Docket_12-EPIC-01.pdf

prepare and submit to the Legislature no later than April 30 of each year an annual report in compliance with Section 9795 of the Government Code that shall include all of the following:

- A brief description of each project for which funding was awarded in the immediately prior calendar year, including the name of the recipient and the amount of the award, a description of how the project is thought to lead to technological advancement or breakthroughs to overcome barriers to achieving the state's statutory energy goals, and a description of why the project was selected.
- A brief description of each project funded by the EPIC Program that was completed in the immediately prior calendar year, including the name of the recipient, the amount of the award, and the outcomes of the funded project.
- A brief description of each project funded by the EPIC Program for which an award was made in the previous years but that is not completed, including the name of the recipient and the amount of the award, and a description of how the project will lead to technological advancement or breakthroughs to overcome barriers to achieving the state's statutory energy goals.
- Identification of the award recipients that are California-based entities, small businesses, or businesses owned by women, minorities, or disabled veterans.
- Identification of which awards were made through a competitive bid, interagency agreement, or sole source method, and the action of the Joint Legislative Budget Committee pursuant to paragraph (2) of subdivision (g) for each award made through an interagency agreement or sole source method.
- Identification of the total amount of administrative and overhead costs incurred for each project.

Coordination with Other Research, Development and Demonstration Efforts

The Energy Commission will stay up-to-date with both in-state and national research, development, and demonstration (RD&D) activities. Agencies with energy-related activities such as the United States Department of Energy (U.S. DOE), the United States Department of Defense (U.S. DOD), the CPUC, and the California Air Resources Board (ARB) can provide key input into the EPIC gap analysis and road mapping activities. In the past, Energy Commission staff has participated in U.S. DOE's research planning, project scoring, and/or program evaluation activities. This coordination is an invaluable tool both to avoid duplication and to leverage related efforts. The U.S. DOE and California's energy agencies (the CPUC, the ARB, the California ISO, and the Energy Commission) have initiated a high-level dialogue to facilitate improved collaboration.

At the request of Energy Commission Chair Robert Weisenmiller, the Energy Commission's Energy Research and Development Division is collaborating with the U.S. DOE to leverage public research dollars in California. On June 4, 2013, the Energy Commission entered into a Memorandum of Understanding with the U. S. DOE's Advanced Research Projects Agency (ARPA-E) to maximize coordination of funding opportunities. ARPA-E funds the development and deployment of transformational energy technologies and systems. Consistent consultation and coordination between the Energy Commission and U.S. DOE improved funding processes, provided cost-share opportunities to potential awardees and maximized the public/ratepayer benefits associated with innovative energy technologies. The Energy Commission and ARPA-E meet twice a year. Under the current administration, the proposed federal budget reduced DOE's funding by $1.7 billion (six percent) and eliminated the ARPA-E program. While this is not the final approved budget, the Energy Commission is preparing for a transition in federal priorities.

California's national labs, academic institutions and other private organizations are leaders in clean energy research innovations. The Energy Commission will encourage participation across the state in EPIC implementation through public stakeholder workshops and meetings and outreach efforts. Interested individuals can provide input on implementing of the *EPIC 2018-2020 Investment Plan*; identify synergies and path to market opportunities, and sharing of program results.

The Energy Commission is committed to on-going collaboration with the three utility administrators at least twice a year. Coordination meetings have been valuable in developing this *EPIC 2018-2020 Investment Plan* to identify each administrator's area of focus, and to suggest synergistic opportunities to collaborate. On-going collaboration will be a cornerstone of the program to assure EPIC activities return the highest benefit to California ratepayers.

Changing Federal Landscape

The 2016 presidential election marked the beginning of significant changes to federal priorities. The President's budget blueprint includes significant cuts to the Department of Energy, including the elimination of the ARPA-E program, as well as significant cuts to the Environmental Protection Agency, and discontinuing funding for the Clean Power Plan.[203] The President's Executive Order 13783 signed on March 28, 2017 also rescinds a number of policies aimed at reducing GHG emissions and addressing climate change.[204] These early actions from the new administration clearly show that clean energy development is not a priority for the administration. However, it remains a high priority for California and many other states. Due to this reduced federal support California's efforts will become that much more significant, as the state continues to lead the way to transforming the energy sector.

Outreach

Advancing pre-commercial energy technologies and approaches can only reach its full potential when current information about funded activities and improvements is available to the appropriate audiences, stakeholders, and users. Stakeholders who will be engaged through outreach include state legislators, government officials, utilities, investors, the California ISO, consumer groups, environmental groups, agricultural organizations, academics, the business community, the energy efficiency community, the clean energy industry, and other industry associations. The Energy Commission is committed to ensuring that information regarding EPIC-funded projects and activities is available to these groups, and will employ a variety of techniques to disseminate information. Through coordination with its Energy Research and Development Division, Media and Public Information Office, Office of Governmental Affairs, and leadership offices, the Energy Commission will ensure that its implementation and administration of EPIC-

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203 https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/budget/fy2018/2018_blueprint.pdf
204 https://www.whitehouse.gov/the-press-office/2017/03/28/presidential-executive-order-promoting-energy-independence-and-economi-1

funded innovations results in effective information sharing. The following avenues for outreach are not intended to be a complete or exclusive list of the Energy Commission's work to this effect, but rather a summary of main activities. These activities will also reflect and adhere to all applicable state policies regarding the sharing of information as well as guidance from the Legislature regarding the inclusion of women-, minority-, and disabled veteran-owned businesses, small businesses, and disadvantaged groups in energy innovation.

Figure 12 EPIC Funding Opportunity Postcards in Multiple Languages

Source: California Energy Commission

Outreach through Partnerships and Coordination

Energy Commission staff's knowledge of energy innovation will be linked with the expertise of its partners, funded researchers, industry, and policy decision makers to ensure the results of EPIC-funded work are applied. Our outreach work will directly complement and advance the technical and market facilitation projects that are funded by EPIC- for example, with the development of the Regional Energy Innovation Clusters to facilitate entrepreneurship. The Energy Commission will also use professional industry networks and forums to share project highlights and significant findings. Technical Advisory Committees and Project Advisory Committees will provide recommendations for information dissemination and technical transfer priorities that are specific to each project and their industry. The Energy Commission will use these expert recommendations to maximize the strategic and meaningful distribution of project findings. Energy Commission collaboration with local, state, and federal agencies will also help ensure that information about innovation advancements is shared with the appropriate regulatory and energy authorities.

Dissemination via Media Awareness, Public Information, and Education Efforts

The Energy Commission will employ the best practices of media outreach to disseminate information about EPIC-funded innovations. Its Media and Public Communications Office will work with the Energy Research and Development Division and Commission leadership to facilitate media inquiries, share newsworthy and timely advancements with appropriate media outlets, and spread updates via social media channels. The Energy Commission maintains an active Facebook, Twitter, and Blog to educate and inform the general public about Energy Commission activities and opportunities.[205] The Energy Commission has also created a LinkedIn group page to provide a user-driven platform to help potential applicants – including disabled veteran-, women- and minority-owned businesses – connect and partner on proposals for solicitations funded through the EPIC Program.[206]

EPIC projects that are of interest to the scientific community will be featured in scientific journals or trade publications. While these feature articles are not guaranteed, the Energy Commission will seek every opportunity to highlight EPIC-funded projects to drive industry forward and extend the reach of R&D efforts. These articles will provide more depth and project detail than fact sheets and describe the project's influence on policy development or industry momentum.

Project Fact Sheets and Reports

The Energy Commission develops a fact sheet for each project funded through EPIC. Fact sheets are posted on the Energy Commission website and provide the public, stakeholders, and decision makers with current information on projects funded through EPIC. Projects can take several years from start to conclusion. The fact sheet, a one- to two-page summary, is a useful tool to keep all interested parties informed. For non-research projects, like local government planning and permitting and workforce development activities, project fact sheets will describe project outcomes and identify lessons learned as well as best practices.

Projects funded through EPIC will also conclude with the production of a final technical report that thoroughly describes the issue or problem addressed by the research, the approach and analysis, any findings, and recommendations for follow-up activities.

205 The Energy Commission's Facebook page: https://www.facebook.com/CAEnergy/; Twitter page: https://twitter.com/CalEnergy; and Blog: http://calenergycommission.blogspot.com/
206 https://www.linkedin.com/groups/6925861

Figure 13 Project Fact Sheet on the Energy Innovation Showcase Website

CA.GOV — CALIFORNIA ENERGY COMMISSION ENERGY INNOVATION SHOWCASE

energy.ca.gov | Contact Us | Quick Links

Search projects

HOME | SEARCH

Search Home / Search Results / Project

City of Fremont Fire Stations Microgrid Project

City of Fremont fire station microgrids manage local, clean energy resources for greater reliability

The Issue

California needs to make better use of locally available renewable energy to increase resiliency and address climate change impacts such as increased fires, severe storms, and heatwaves. Critical facilities are especially vulnerable to climate change impacts that disrupt the normal delivery of energy needed for their operation. Microgrids could help increase the resiliency of critical facilities through maximizing use of local renewable energy. Microgrid demonstrations at fire stations will develop a case study to assess their ability to support fire station operations and safely island from the grid.

Project Innovation

This project will design and build low carbon-based microgrids at three fire stations in Fremont, California. Each microgrid consists of a microgrid energy management system, parking lot canopy photovoltaic system, and battery energy storage. The automated microgrid control system will optimally manage local energy resources and loads. The microgrid will provide at least three hours a day of power for critical loads during a utility power outage.

Project Benefits

The microgrids will attempt to reduce grid congestion which increases grid reliability. The microgrids will demonstrate their ability to improve energy efficiency by optimizing power generation and loads using advanced, automated microgrid control. Local, renewable photovoltaic generation and energy storage may provide increased energy security during utility power outages and reduce carbon dioxide emissions.

Greater Reliability: This project will attempt to reduce congestion and improve resiliency for the distribution system by using local photovoltaic generation, thus reducing the utility load where substations are near maximum capacity. The fire stations will have greater reliability by using local energy resources during a utility outage, at least three hours a day.

Environmental Benefits: This project will reduce carbon dioxide emissions by using local clean power generation (solar photovoltaics) and energy storage when available. This emissions reduction will help the City of Fremont meet its goal of reduced greenhouse gas emissions by 2020 and achieve its zero net energy goals for city government buildings.

Energy Security: The fire station microgrids will provide at least three hours a day of electricity to critical loads during utility power outages. The fire stations are vulnerable to earthquakes from the nearby Hayward faults, so having local, renewable generation decreases their dependence on outside electricity sources.

For questions or additional information, please email RandDProjectinfo@energy.ca.gov

Project Overview

Recipient: Gridscape Solutions

Program: EPIC

Award Amount: $1,817,925

Co-funded Amount: $657,260

Agreement Number: EPC-14-050

Project Term: 5/8/2015 - 3/31/2018

Project Status: Active

Recipient Location: Fremont, CA

Site Location(s): Fremont, CA

Project Team

CEC Project Manager: Qing Tian

Recipient Contact: Vipul Gore

Match Partner(s): City of Fremont; Gridscape Solutions; Delta Products Corporation; Microgrid Energy

Subcontractor(s): Delta Products Corporation; Microgrid Energy; Jim Willson

Source: California Energy Commission

EPIC Symposium

Once a year the EPIC administrators host an EPIC Symposium to showcase and share project results from EPIC funded research. The Symposium is designed to help researchers, builders, government agencies, innovators and the public engage and learn more about cutting-edge energy strategies that are helping to evolve California's electricity system. The first EPIC Symposium was held on December 3, 2015 in Folsom, CA, and the second one was held on December 1, 2016 in Sacramento, CA.

Energy Commission Website

Project fact sheets, final reports, and other documents related to, or supported by, EPIC funds will be publicly accessible on the Energy Commission website to maximize transparency and increase value for the program and its projects. The Energy Commission website will also serve as a resource for Energy Commission proceedings related to the development of the *EPIC 2018-2020 Investment Plan*. On the website, interested stakeholders will be able to navigate to EPIC policy documents, past workshop presentations, funding solicitations, annual EPIC reports, and other resources that will facilitate active participation in the program. The EPIC website is: http://www.energy.ca.gov/research/epic/.

In 2016, The Energy Innovation Showcase was launched by the Energy Commission as a graphically visual webpage that gives insight to the various projects, lists the award recipients and funding amount and explains how the project benefits ratepayers. Projects can be searched by location, by areas of support, and by research topics. The page also highlights the Energy Commission's goal of increasing diversity in the energy sector and its expanded outreach to efforts to women, minority, disabled veteran, and LGBT communities. The Energy Innovation Showcase website is: http://innovation.energy.ca.gov/

Figure 14 Energy Innovation Showcase Homepage

Source: California Energy Commission

EPIC Agreements

The EPIC Program, with limited exceptions, awards funds through a competitive bid process, as required by the Public Resources Code Section 25711.5. The majority of initiatives included in this *EPIC 2018-2020 Investment Plan* will be implemented through the Energy Commission's competitive solicitation process to ensure a fair, open, and transparent opportunity for interested parties. The procedures for competitive solicitations will follow applicable requirements from the State Contracting Manual, State Public Contracts Code, Public Resources Code, and other laws and regulations, such as civil service restrictions, prevailing wages, and the California Environmental Quality Act.

EPIC solicitations will typically be open to all public and private entities and individuals interested in electricity-related applied R&D, TD&D, and market facilitation. However, some solicitations may target specific entities, such as universities or local governments; locations, such as disadvantaged communities; or prohibit certain applicants if their participation could represent a conflict of interest.

Under Legislative oversight, as described in PRC 25711.5, the Energy Commission may use a sole source or interagency agreement to award funds if the project cannot be described with sufficient specificity so that bids can be evaluated against specifications and criteria set forth in a solicitation for bid and if both of the following conditions are met:

- The Energy Commission, at least 60 days prior to making an award pursuant to this subdivision, notifies the Joint Legislative Budget Committee and the relevant policy committees in both houses of the Legislature, in writing, of its intent to take the proposed action.
- The Joint Legislative Budget Committee either approves or does not disapprove the proposed action within 60 days from the date of notification.

In 2016, the Energy Commission made non-competitive awards for a total of $2.5 million to three California universities in an effort to leverage substantial federal funding while enhancing California-specific research scope and products from the Clean Energy Research Center for Water Energy Technologies (CERC-WET). These three agreements represent the only non-competitive awards made under EPIC thus far in the program.

Solicitation Process

Solicitations are developed in alignment with one or more strategic initiatives identified in one or more of the EPIC Investment Plans. Solicitation objectives are designed to remove specific clean energy deployment barriers and are mapped to achieve specific clean energy goals. These objectives are typically derived from a roadmap, through stakeholder workshops or responses to a questionnaire sent to stakeholders on the EPIC list serve, or from expertise gained in current research projects.

Once a solicitation is developed it is publically noticed through a number of available list servers,[207] and a LinkedIn subgroup that is created to encourage collaboration among interested stakeholders. The solicitation, either a Grant Funding Opportunity (GFO) or a Request for Proposal (RFP) is posted on the Energy Commission's website. All the information necessary to submit a proposal, including the solicitation's objectives, requirements, scoring criteria, and application form and all other templates

207 To register for the EPIC List Serve: http://www.energy.ca.gov/research/epic/.

that must be used in the proposal. Each solicitation will identify the terms and conditions to be used in the solicitation.

The vast majority of EPIC agreements are awarded through a competitive grant (GFO) process, thus the discussion below is focused around that solicitation type. EPIC funds awarded through a competitive contract process largely align with the GFO process, there are additional requirements placed on this process that requires the Energy Commission to adjust the solicitation process. An example of the difference is the implementation of an online application submission option for applicants of GFOs that cannot be extended to applicants of RFPs because of the additional requirements.

Shortly after a solicitation has been posted, Energy Commission staff will hold a publicly noticed workshop to review the solicitation purpose, requirements, eligibility, and research topics with interested parties. The public workshop will provide an opportunity for potential applicants to ask questions on the solicitation and the application process. There will also be an opportunity for interested parties to submit written questions about the solicitation. The staff's responses to all questions will be posted on the Energy Commission website to ensure that all potential applicants have access to the same information. Any revisions, corrections, and clarifications on the solicitation will also be posted on the Energy Commission website and announced through the appropriate listserve(s). An estimation of a typical one-phase solicitation schedule is shown in Table 58.

Table 58: Solicitation Timeline

Estimated Solicitation Schedule	**Approximate Timeline (calendar days)**
Solicitation Release	Day 0
Pre-Application Workshop	Day 18
Deadline for Written Questions	Day 20
Post Questions, Answers and Addenda to Website	Day 50
Deadline to Submit Applications	Day 80
Post Notice of Proposed Awards	Day 130
Business Meeting Date	Day 240
Agreement Start Date	Day 270

Source: California Energy Commission

Some solicitations may use a two-phase selection process. The first phase involves preparing a brief abstract to determine technical merit. The abstract will be evaluated on a pass/fail or scoring scale basis according to specific criteria. The abstract must pass all criteria (if using pass/fail basis) or achieve a minimum score on all criteria (if using a scoring scale) to proceed to the second phase and submit a full proposal. The full proposal will be evaluated in the same manner as a proposal for a one-phase solicitation. Additional information on the evaluation process for the first phase in a two-phase solicitation can be found below.

Once the scoring for a solicitation is complete the proposals will be ranked and a

Notice of Proposed Award (NOPA) will be released showing the rank of each proposal based on overall proposal score, applicant name, funds requested and staff funding amount recommended, match funding and score status. Funding will first be awarded to the top ranked proposal and then to the next ranked proposal until all funds have been expended. A sample NOPA is shown in Table 59.

Table 59: Sample NOPA

Name of Bidder/Applicant	Funds Requested	Funds Awarded	Match Amount	Score	Status
A Company	$1,000,000	$1,000,000	$200,000	83.5	Awardee
B Company	$500,000	$500,000	$5,000	80	Awardee
C Company	$3,000,000	$3,000,000	$200,000	79.5	Awardee
D Company	$2,000,000	$0	$10,000	77	Finalist*
E Company	$2,000,000	$0	$100,000	-	Did not pass
F Company	$500,000	$0	$5,000	-	Did not pass
G Company	$2,000,000	$0	$20,000	-	Disqualified
Total	$11,000,000	$4,500,000			

*To be awarded only if additional funds are available
Source: California Energy Commission

After the NOPA is released, all the applicants will be notified of the results and an Energy Commission representative will begin working with the awardees to develop an agreement for the awarded project. Once the agreement is finalized it will be presented and voted on at an Energy Commission Business Meeting. After approval at an Energy Commission Business Meeting the contract will be signed by all parties and work may begin on the project.

Evaluating Proposals for Single Phase Solicitations

Single phase solicitations are evaluated in two stages, proposal screening and proposal scoring. Proposal screening is a series of pass/fail administrative requirements that all proposals must pass to proceeding to the scoring process. Proposals that do not pass the administrative screening are disqualified and will not move on to the scoring stage. An example of the administrative screening criteria can be found in Table 60. While the majority of these criteria are applicable for all solicitations, some criteria may be removed, added, or revised for specific solicitations based on the specific objectives and requirements of that solicitation.

Table 60: Sample Administrative Screening Criteria

EXAMPLE SCREENING CRITERIA *The Application must pass ALL criteria to progress to Stage Two.*	**Pass/Fail**
The application is received by the Energy Commission's Contracts, Grants, and Loans Office by the due date and time specified in the "Key Activities Schedule" in Part I of this solicitation and is received in the required manner.	☐ Pass ☐ Fail
The application Form is signed where indicated.	☐ Pass ☐ Fail
The application addresses at least one of the funding initiatives, as indicated in the Solicitation.	☐ Pass ☐ Fail
If the applicant has submitted more than one application for the same project group, each application is for a distinct project.	
The requested funding falls within the minimum and maximum range specified in the solicitation.	☐ Pass ☐ Fail
The application form and budget specify that the applicant will provide at match funding meeting or exceeding the requirements of the solictiation. The porposal includes commitment letters for all match funding specified.	☐ Pass ☐ Fail
If applicable the application form identifies one or more test, demonstration, or deployment site locations. The proposal includes a site commitment letter from each of these sites.	☐ Pass ☐ Fail ☐ N/A
The application does not contain any confidential information or identify any portion of the proposal as confidential.	☐ Pass ☐ Fail

Source: California Energy Commission

Proposals that pass the administrative screening process are then scored by a committee consisting of Energy Commission staff and other contributors that do not have a conflict of interest. This scoring committee may receive assistance from internal or external technical reviewers when needed. The scoring committee will use the set of technical scoring criteria and assigned point values published in the solicitation manual to evaluate each proposal. These criteria helps ensure that the proposed project has merit, is feasible and does not duplicate other efforts, the team is qualified and the budget is reasonable. While the Technical scoring criteria will typically remain the same for all EPIC solicitation, the specifics on how each criterion will be evaluated for a specific solicitation will differ, depending on the specific solicitation objectives and expected products. Example scoring criteria are provided in Table 61.

Table 61: Example Technical Scoring Criteria

Maximum Points	Technical Scoring Criteria
20	**Technical Merit and Need** This Criterion will evaluate the goals and objectives of the project. Applicants will be required to summarize the current state of the relevant technology, scientific, or market and innovation knowledge and explain how the project will achieve the desired advancements. The applications will need to justify the need for EPIC funding and the feasibility and achievability of the project in the time allotted and with the funds requested.
20	**Technical Approach** The criterion will evaluate the proposed approach for completion of the project, including the scope of work, methods used to perform the work, plans to address barriers and limitations, public dissemination of the knowledge gained, and other factors critical to a successful approach.
20	**Impacts and Benefits to California IOU Ratepayers.** This criterion will evaluate what the benefits of the project will be, if successful, to California's IOUs ratepayers with respect to the EPIC goals of greater reliability, lower costs, and/or increased safety. This could include the improvement of the proposed technology over the existing alternatives, the anticipated cost reductions, potential for customer adoption, estimates for commercialization and market adoption, environmental impacts, customer desirability, and other characteristics as appropriate for the focus of the solicitation.
10	**Team Qualifications, Capabilities, and Resources** This criterion will be used to evaluate not only the qualifications of the team, the capabilities of the primary applicant and project partners, the organization of the team, and the resources available to the team, but also how those qualifications, capabilities, and resources will contribute to the successful completion of the project. Also evaluated in this section is the support or commitment the project has received from entities that are not a part of the project team.
10	**Budget and Cost Effectiveness** This score will be based on the budget and associated justification for the project. This could include, but is not limited to, labor costs, labor hours, materials, equipment, non-labor costs, operating expenses, travel, and other expenditures specified in the budget.

Table 61: Example Technical Scoring Criteria

<table>
<tr><th>Maximum Points</th><th>Technical Scoring Criteria</th></tr>
<tr><td>15</td><td>

Funds Spent in California

Projects that spend EPIC funds in California will receive points as indicated in the table below.

<table>
<tr><th>Percentage of EPIC funds spent in CA</th><th>Percentage of Possible Points</th></tr>
<tr><td>>60%</td><td>20%</td></tr>
<tr><td>>70%</td><td>40%</td></tr>
<tr><td>>80%</td><td>60%</td></tr>
<tr><td>>90%</td><td>80%</td></tr>
<tr><td>>98%</td><td>100%</td></tr>
</table>

</td></tr>
<tr><td>5</td><td>

Ratio of Direct Labor and Fringe Benefit Rates to Loaded Labor Rates

This criterion is applied the totals for the entire project.

- $Points = Maximum\ Points \times \frac{(Direct\ Labor + Fringe)}{(Direct\ Labor + Fringe + Indirect + Profit)}$

</td></tr>
<tr><td></td><td>

Preference Points, if applicable

Solicitations may include the use of preference points for proposals to encourage proposals with particular characteristics. Preference points will only be awarded proposals that have met the minimum requirements to be awarded funds in the solicitation. Examples of preference point systems that could be used are:

Match Funding: preference points may be awarded to proposals that provide match funding in excess of the minimum match requirements for a solicitation. Applicants who choose to commit more of their own funds or secure addition funding are typically more invested in the success of a project and the later commercialization of a technology.

Location of a demonstration site in a Disadvantaged Community. The benefits of advanced energy technologies typically do not accrue to Disadvantaged Communities at the same rate as other parts of the state. Preference points may be used to encourage researchers to focus on technologies that will provide benefits to these communities.

</td></tr>
</table>

Source: California Energy Commission

Scores will be based off the scoring scale shown in Table 62. Each scorer will separately score all proposals prior to a scoring meeting when the scoring committee will discuss the proposals and finalize their scores. As specified in each solicitation, proposals may be required to achieve a minimum passing score on certain criteria, or groups of criteria, in order to be considered for an award. The total minimum passing score is typically 70 out of 100 points. Once the scoring process is complete a NOPA is created as described above.

Table 62: Sample Scoring Scale

% of Possible Points	Interpretation	Explanation for Percentage Points
0%	Not Responsive	• The response fails to address the criteria. • The omissions, flaws, or defects are significant and unacceptable.
10-30%	Minimally Responsive	• The response minimally addresses the criteria. • The omissions, flaws, or defects are significant and minimally acceptable.
40-60%	Inadequate	• The response addresses the criteria • There are one or more omissions, flaws, or defects or the criteria are addressed in such a limited way that it results in a low degree of confidence in the proposed solution.
70%	Adequate	• The response adequately addresses the criteria. • Any omissions, flaws, or defects are inconsequential and acceptable.
80%	Good	• The response fully addresses the criteria with a good degree of confidence in the applicant's response or proposed solution. • There are no identified omissions, flaws, or defects. Any identified weaknesses are minimal, inconsequential, and acceptable.
90%	Excellent	• The response fully addresses the criteria with a high degree of confidence in the applicant's response or proposed solution. • The applicant offers one or more enhancing features, methods, or approaches exceeding basic expectations.
100%	Exceptional	• All criteria are addressed with the highest degree of confidence in the applicant's response or proposed solution. • The response exceeds the requirements in providing multiple enhancing features, a creative approach, or an exceptional solution.

Source: California Energy Commission

Evaluating Proposals for Two Phase Solicitations

Some solicitations may use a two-phase selection process. The first phase involves preparing a brief abstract that will be used to determine technical merit of the proposal. If the proposal passes the first phase of evaluation, the applicant will be invited to submit a full application which will be evaluated in the same manner as a single phase proposal.

The first phase of a two phase solicitation will be evaluated either on a pass/fail or scoring scale basis according to specific criteria identified in the solicitation manual. For solicitations using a pass/fail basis, the proposal must pass all identified criteria to proceed to the section phase. Solicitations using a scoring basis will specify a minimum score that must be achieved by the abstract to proceed to the second phase.

An example of possible criteria is included below in Table 63 The criteria used in an actual solicitation may include additional detail, sub criteria, or be revised to better align with the purpose of the solicitation and critical points of evaluation that will be effective in determining which proposals merit additional review.

Table 63: Sample Phase One Evaluation Criteria

Administrative Evaluation Criteria	
Pass/Fail	**Criteria**
P/F	The stage one proposal was received by the Energy Commission’s Grants and Loans Office by the due date and time specified in the “Key Activities Schedule” in Part I of this solicitation, and the Application Form includes all required information and is signed by an Authorized Representative.
P/F	The proposal includes a timeline for the project, and the duration does not extend past the time specified in the solicitation manual.
P/F	The proposal is submitted and organized in accordance with the instructions in the solicitation.
P/F	The proposal does not contain any confidential information or identify any portion of the application as confidential.
P/F	If the applicant has submitted more than one proposal for the same project category, each proposal is for a distinct project.
Technical Evaluation Criteria	
P/F or Points	**Criteria**
	Alignment of the project with the purpose of the solicitation.
	Are the objectives of the project realistic and achievable in the project timeframe?
	Does the project adequately address the technical and implementation issues or barriers to further development and deployment of this technology?
	Is the project appropriate for the development stage of the technology?

	Does the project team include expertise necessary to perform the work described?
	Does the project team have access to the necessary resources and facilities to perform the work described?
	Are the requested funds sufficient without being excessive to complete the work described?
	Is the demonstration site is appropriate for the proposed research, and has provided a letter of intent to participate in the project.
	Has a letter(s) of support been provided? Does the letter demonstrate a desire to make use of the proposed development in the technology?

Source: California Energy Commission

Project Management

A project agreement establishes a contractual relationship between the Energy Commission and the recipient of EPIC funds. A Commission Agreement Manager (CAM) will be assigned to the project and will be responsible for coordinating with funding recipients, and serving as the Energy Commission's point of contact for stakeholders interested in receiving more information about the project. The CAM also provides technical oversight of the project, reviewing and providing feedback on all deliverables, and ensuring that the project adheres to the scope and schedule that was agreed upon by the Energy Commission and the recipient.

All EPIC recipients will be required to participate in kick-off meetings to establish deliverable expectations, roles and responsibilities, accounting procedures, and reporting requirements; submit monthly or quarterly progress reports to ensure the contractor is complying with the task schedules specified in the contractual agreement; and provide final documentation in the form of data, engineering plans, final construction and operation of facilities, or final reports documenting research results and other contractual deliverables.

EPIC projects will typically include a technical or project advisory committee (TAC). These committees may be composed of diverse professionals, academics, technology experts, and regulatory specialist. The TAC can provide valuable perspective and guidance on the project related to the direction of the project, the content of deliverables, and information dissemination and market strategies relevant to the project. The number and composition of the committee members can vary depending on potential interest and time availability. The recipients will be responsible for proposing TAC members for the project, and reaching out to form the TAC; however, the committee members will serve at the discretion of the CAM.

EPIC projects will also usually include at least one critical project review meeting at a pre-designated milestone(s) in which the CAM will review the progress to date and determine whether the progress to date justifies proceeding to the next phase of the project and make necessary corrections to ensure project success. CAMs may also call a critical project review at any time during the project, if the CAM believes there is a significant issue with the progress or administration of the project that needs to be discussed, and could result in a change to the project or its termination. This is an important management tool for projects that do not always meet their initial goals and decisions need to be made whether to terminate or re-scope a project based on interim findings.

Terms and Conditions

These terms and conditions set forth the recipient's rights and responsibilities. When submitting a proposal, the applicant must sign the Application Form. By signing the form, each applicant agrees to use the version of the EPIC grant or contract terms and conditions that corresponds to its organization, without modification: (1) University of California and California State University terms and conditions; (2) National Laboratory terms and conditions; or (3) standard terms and conditions. The terms and conditions are shown on the Energy Commission's website: www.energy.ca.gov/research/contractors.html.

Intellectual Property

Intellectual property (IP) refers to products of the mind protected by law such as copyrights, trademarks, and patents. One of the basic benchmarks of any RD&D program is whether it results in new, commercially successful technology. IP rights play a significant role in commercialization. For example, IP rights that inappropriately share ownership or make proprietary information public would prevent the commercialization of new technologies. An entity would no longer have a competitive advantage, and thus no longer have the impetus for developing new technology. However, IP rights must also allow the sharing of new scientific knowledge which fosters further advances and prevents duplication of efforts by others, which in turn preserves RD&D funds for new efforts.

Details of the standard IP rights under EPIC can be found in the Electric Program Investment Charge (EPIC) Standard Grant Terms and Conditions, Sections 20 – 22 (http://www.energy.ca.gov/research/contractors.html). These were developed with the directions in the CPUC's Decision 13-11-025 and Public Resources Code Section 25711.5. The following are some key areas:

- As directed by statute, the Energy Commission consulted with the California State Treasurer's Office in developing the IP terms.
- Each EPIC RD&D project needs to identify the IP that it will create in the form of new technology, advances in existing technology, or advances in scientific knowledge, and how the new IP will benefit the contributing ratepayers.
- In general, the rights of IP developed under EPIC will be held by the entity developing it. The Energy Commission and the Public Utilities Commission have licenses to use the IP to benefit EPIC ratepayers.
- The EPIC Program will have march-in rights to take IP that entities who accept EPIC funds develop but do not use. This will protect the ratepayers' investment in the IP and ensure that the benefits from the developed IP are received.
- IP derived from general energy research that is geared towards new knowledge rather than product development should be put in the public domain, made publically available, or if kept by the entity, used such that the results are made public (for example, the University of California or national labs might keep the copyright to research papers, but then publish the results to make them known and available). This advances science and prevents other entities from performing duplicate research.

- Royalties will be collected as indicated in Section 22 of the terms and conditions. The requirements can be found at: http://www.energy.ca.gov/research/contractors.html.

Currently, the Energy Commission's terms allow it and the CPUC to grant intellectual property licenses to load-serving entities, which include the IOUs. The licenses allow load-serving entities to utilize EPIC-funded intellectual property in their service to EPIC ratepayers.

In September 2016, Energy Commission staff held a public workshop to better understand potential barriers that may deter private sector companies from applying for EPIC funding opportunities. Workshop participants, including entrepreneurs and private investors, raised concerns that the term allowing licenses to load-serving entities deters EPIC applicants. Fewer applicants mean less competition. Less competition can mean EPIC ratepayers are not receiving the best projects for their funds.

The Energy Commission seeks to clarify this term as applicable to all investment plans to what it believes is the intent to grant load-serving entities (LSE) with a free license to use models and analytical tools that can inform distribution planning and decision-making that benefits electric ratepayers.

For example, the recently completed EPIC project *Validated and Transparent Energy Storage Valuation and Optimization Tool* developed a publicly accessible and customizable model for energy storage benefit-cost analysis. If the recipient decided to charge a subscription or other fee for load-serving entities to use the tool, the Energy Commission or CPUC could grant the IOU's or other load-serving entities free access to its use.

No licenses are to be granted for any other type of developed technology. For example, if an EPIC recipient develops and files a patent for a new type of solar PV technology, no license will be granted to an LSE since they would not be manufacturing developed EPIC technologies.

The Energy Commission believes this clarification is consistent with Ordering Paragraph 50 of CPUC Decision D. 13-11-025 which states, "Consistent with state law and our decision concerning the fair licensing of intellectual property (IP) to load-serving entities (LSEs) or other utility competitors serving ratepayers, to the extent the grantees proprietary and competitive interests are appropriately and adequately protected, the licensing of IP must be done on fair, reasonable, and non-discriminatory terms, including but not limited to a fair and reasonable licensing costs charged to LSEs or other utility competitors."

Clarifying this term does not change the existing royalty terms. Thus, to the extent EPIC projects result in commercialized technologies, EPIC ratepayers will still benefit from the royalties paid.

Funding and Cost Considerations

Administrative Cost Containment

The Energy Commission will monitor its administrative costs to manage the EPIC Program within the 10 percent cap established in the CPUC's EPIC decision.

Integrating Source(s) of Funding in a Solicitation

The typical solicitation will be EPIC funding only. However, the Energy Commission recommends allowing a combination of funding sources in the same solicitation when it adds value to the ratepayers. For example, some barriers and solutions may benefit from an integrated electricity and natural gas approach. It could be beneficial to include EPIC funding and natural gas funding together in the same solicitation because some initiatives (for example, HVAC or building envelope) can have both electric and natural gas savings. Having a joint solicitation will capture the synergy associated with both fuel savings. Any such use of multiple funding sources will be clearly identified in the funding opportunity notice and all proposals will be required to demonstrate how the proposed project will provide benefits to both electric and natural gas ratepayers.

EPIC Program Benefits

All energy research and development (R&D) programs using ratepayer dollars must demonstrate a reasonable probability of achieving ratepayer benefits in selecting those R&D projects. For EPIC, the Energy Commission is using a program-wide approach to assess ratepayer benefits including integrating benefit and cost assessment elements into solicitation planning, project implementation, and project evaluation.

The Energy Commission will implement prospective and retrospective benefits assessment. Prospective assessments that are targeted and integral to the planning and project process can estimate potential benefits based on size of the sector, magnitude of the barrier, and solutions that are targeted. Retrospective assessments will be conducted at project closeout to capture achieved benefits and projected future benefits.

Project specific data for these assessments will be collected through the project proposal and three benefits questionnaires that awardees will be required to submit during the course of the project. Using the information provided by recipients, publicly and privately available datasets, and analysis tools, Energy Commission staff will evaluate the potential and actual ratepayer benefits of each project.

The Energy Commission will strategically focus on a sample of closed projects that merit in depth analysis to determine represented quantitative and qualitative benefits. Additionally, the Energy Commission will validate the researcher's or award recipient's method(s) to measure benefits, and when possible use standard assumptions and models to evaluate the benefits. The Energy Commission will share the benefits information in published project fact sheets, project final reports, annual reports to the CPUC, and through other avenues such as published technology brochures and trade journals.

In all cases, the Energy Commission will document the steps of benefits assessment and transparently present the uncertainties in the benefits calculations. Moreover, the Energy Commission will evaluate the EPIC Program benefits assessment processes by working with other benefits assessment practitioners, including government and other research organizations, to continually evaluate and improve the EPIC Program benefits assessment process.

Metrics and Areas of Measurement

The CPUC Decision 12-05-037 determined the primary and mandatory guiding principle of the EPIC Program is to provide electricity ratepayer benefits, defined as promoting greater reliability, lower costs, and increased safety. In addition, the CPUC adopted these complementary guiding principles:

- Providing benefits to ratepayers.
- Achieving greenhouse gas (GHG) emissions mitigation and adaptation in the electricity sector at the lowest possible cost.
- Sustaining the Loading Order.

- Advancing low-emission vehicles/transportation.
- Supporting economic development.
- Using ratepayer monies efficiently.

The CPUC Decision 13-11-025 modifies the EPIC Administrators' investment plans by adopting a list of proposed metrics and potential areas of measurement "that may be evaluated and/or measured in preparing solicitation materials, performing project work, assessing project results, and preparing annual reports for the EPIC Investment Plans."[208,209] The decision states that EPIC Administrators "may choose metrics on a project-by-project basis from those included as Attachment 4 or additional metrics where appropriate. However, the Administrators must identify those metrics in the annual report for each project."[210] The following proposed measurement areas are identified in the list adopted by the CPUC for the EPIC Program:

- Potential energy and cost savings.
- Job creation.
- Economic benefits.
- Environmental benefits.
- Safety, Power Quality, and Reliability (Equipment, Electricity System).
- Other Metrics (to be developed based on specific projects through ongoing administrator coordination and development of competitive solicitations).
- Identification of barriers or issues resolved that prevented widespread deployment of technology or strategy.
- Effectiveness of information dissemination.
- Adoption of EPIC technology, strategy, and research data/results by others.
- Reduced ratepayer project costs through external funding or contributions for EPIC-funded research on technologies or strategies.

Consistent with EPIC requirements set by the CPUC and the Legislature, the Energy Commission staff will identify the barriers or issues each project aims to resolve and select measurement areas and metrics to be applied for each project. These metrics will be based on the barriers addressed, type of project and technology, energy use sector, and the specific project funded, and the project's development stage in the energy innovation pipeline.

The Energy Commission staff notes the close connection of energy savings, cost savings, job creation, and economic benefits. For example, the cost savings accrued to ratepayers resulting from EPIC-funded research on energy efficiency will have a multiplier effect on California's economy, creating jobs. The Energy Commission staff will determine which benefits and metrics are applicable to the evaluation of each proposal and project based on the barriers addressed, type of project and technology, energy use sector, and the specific project funded, and the project's development stage in the energy innovation pipeline.

The Energy Commission staff is actively working to simplify and streamline the benefits assessment process by developing tools that will use industry standard performance metrics and incorporate information on California's diverse climates and end-users as a complement to measures of success related to project-specific goals and objectives. It is the aim of this effort to simplify the benefits evaluation process for innovators, and be able to provide more robust benefits analyses that can be used to directly compare the benefits of one technology to another.

208 Decision 13-11-025, ordering paragraph 26.
209 Decision 13-11-025, Attachment 4.
210 Decision 13-11-025, ordering paragraph 27.

CHAPTER 11: Conclusion

California has made tremendous progress towards transforming its electricity system to meet the growing demands of a dynamic economy while addressing the threat posed by climate change. Greenhouse gas emissions have decreased over the past decade while generation from renewable energy sources makes up an increasing share of the state's electricity supply. State policy has kept pace with this progress, mandating increasingly far-reaching and aggressive goals for the energy sector to meet.

Energy technologies will need continued advancements to meet future challenges. Growing electricity demand from electrification of sectors like transportation and industry, as well as the unavoidable impacts of climate change expected to come will require new technologies combined with deployment strategies. Innovations at all levels will be needed to drive the scale and reduce the cost of new technologies to achieve wide deployment.

The EPIC program plays a critical role in bringing innovations from ideas to impact. Technology advances are needed for energy efficiency, demand response, microgrids, electric vehicles, energy storage, renewable generation, water efficiency, and other areas. Furthermore, these technical advances must be complimented by innovative deployment strategies and informed decision-making. Advancements in planning, permitting, and financing can reduce barriers to technology deployment, while continued climate science research can provide actionable recommendations for state, regional and local decision makers.

California's clean energy transformation must also focus on equity, and ensure that benefits from these advancements are realized by all Californians, especially those in the most vulnerable communities.

The research initiatives presented in this investment plan will ensure the Energy Commission's EPIC program continues to provide energy leadership and innovation necessary to carry out California's progressive energy policies and inform decisions and actions at local, state, federal and international levels; and further position California as the primary destination for top talent and investment in the clean energy economy.

Next Steps

Through the public workshops held in February, March and April 2017, the Energy Commission gained valuable stakeholder input which helped shape the funding initiatives proposed in this investment plan. The Energy Commission will consider adopting the *EPIC 2018 – 2020 Proposed Investment Plan* at the Business Meeting on April 27, 2017. The Energy Commission will submit a proposed investment plan to the CPUC on May 1, 2017. The anticipated schedule identified in CPUC decision D. 12-05-037 calls for the CPUC to consider the four EPIC Administrator's Investment Plans from May 2017 through November 2017, with anticipated approval in December 2017.

If the investment plan is approved, the Energy Commission will prepare and issue solicitations to fund the initiatives identified in this plan. The Energy Commission looks forward to implementing the EPIC Program and seeing these projects come to fruition for the benefit of ratepayers who fund this program.

APPENDICES

APPENDIX A: Summary of Stakeholder Comments and Energy Commission Staff Responses on the February 3, 2017, Scoping Webinar

APPENDIX B: Summary of Stakeholder Comments and Energy Commission Staff Responses on the March and April 2017 Scoping Workshops

APPENDIX C: Summary of Verbal Stakeholder Comments and Energy Commission Staff Responses on the Electric Program Investment Charge Proposed 2018 – 2020 Triennial Investment Plan

These Appendices are available as a separate volume, publication number:

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