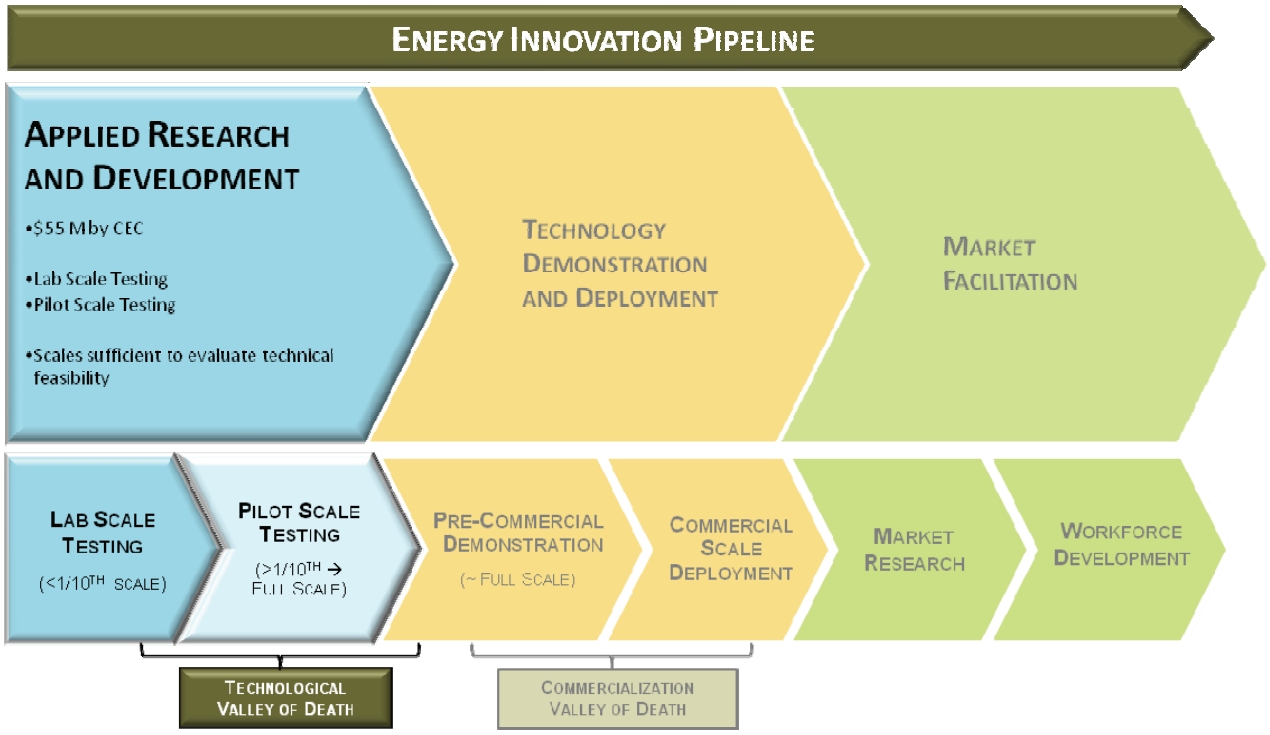
CHAPTER 3:
Applied Research and Development



Source: California Energy Commission.

Through the Applied Research and Development program area, the Energy Commission will address gaps in the funding needed to help innovative energy technologies and approaches bridge the "Technological Valley of Death." For this three-year investment plan, the Energy Commission will provide $158.7 million for applied research and development (R&D) funding for development of new technologies, methods, and approaches from early bench-scale up to pilot-scale prototype demonstration. This will include activities that address environmental and public health impacts of electricity-related activities, support building and appliance standards, and promote clean transportation. Each strategic objective below outlines a set of initiatives focused on a particular area of proposed research. The strategic objectives are:

- **Energy Efficiency and Demand Response**
    - S1 Strategic Objective: Develop Next-Generation End-Use Energy Efficiency Technologies and Strategies for the Building Sector.

- S2 Strategic Objective: Develop New Technologies and Applications That Enable Cost-Beneficial Customer-Side-of-the-Meter Energy Choices.

- **Clean Generation**
  - S3 Strategic Objective: Develop Innovative Technologies, Tools, and Strategies to Make Distributed Generation More Affordable.
  - S4 Strategic Objective: Develop Emerging Utility-Scale Renewable Energy Generation Technologies and Strategies to Improve Power Plant Performance, Reduce Costs, and Expand the Resource Base.
  - S5 Strategic Objective: Reduce the Environmental and Public Health Impacts of Electricity Generation and Make the Electricity System Less Vulnerable to Climate Impacts.
- **Smart Grid-Enabling Clean Energy**
  - S6 Strategic Objective: Develop Technologies, Tools, and Strategies to Enable the Smart Grid of 2020.
  - S7 Strategic Objective: Develop Operational Tools, Models, and Simulations to Improve Grid Resource Planning.
  - S8 Strategic Objective: Integrate Grid-Level Energy Storage Technologies and Determine Best Applications That Provide Locational Benefits.
  - S9 Strategic Objective: Advance Technologies and Strategies That Optimize the Benefits of Plug-in Electric Vehicles to the Electricity System.
- **Cross-Cutting**
  - S10 Strategic Objective**:** Leverage California's Regional Innovation Clusters to Accelerate the Deployment of Early-Stage Clean Energy Technologies and Companies.
  - S11 Strategic Objective: Provide Cost Share for Federal Awards.

Table 8: Proposed Funding Allocation for the Applied Research and Development Program Area by Strategic Objective

Funding Area	Amount (Millions)
Energy Efficiency and Demand Response	**$64.7**
S1 Strategic Objective: Develop Next-Generation End-Use Efficiency Technologies and Strategies for the Building Sector.	$43.3
S2 Strategic Objective: Develop New Technologies and Applications That Enable Cost-Beneficial Customer-Side-of-the-Meter Energy Choices.	$21.4
Clean Generation	**$44.0**
S3 Strategic Objective: Develop Innovative Technologies, Tools, and Strategies to Make Distributed Generation More Affordable.	$19.5
S4 Strategic Objective: Develop Emerging Utility-Scale Renewable Generation Technologies and Strategies to Improve Power Plant Performance, Reduce Costs, and Expand the Resource Base.	$9.5
S5 Strategic Objective: Reduce the Environmental and Public Health Impacts of Electricity Generation and Make the Electricity System Less Vulnerable to Climate Impacts.	$15.0
Smart Grid Enabling Clean Energy	**$23.0**
S6 Strategic Objective: Develop Technologies, Tools, and Strategies to Enable the Smart Grid of 2020.	$8.0
S7 Strategic Objective: Develop Operational Tools, Models, and Simulations to Improve Grid Resource Planning.	$5.0
S8 Strategic Objective: Integrate Grid-Level Energy Storage Technologies and Determine Best Applications That Provide Locational Benefits.	$6.0
S9 Strategic Objective: Advance Technologies and Strategies That Optimize the Benefits of Plug-in Electric Vehicles to the Electricity System.	$4.0
Cross-Cutting	**$27.0**
S10 Strategic Objective: Leverage California's Regional Innovation Clusters to Accelerate the Deployment of Early-Stage Technologies and Companies.	$27.0
S11 Strategic Objective: Provide Cost Share for Federal Awards.*	$ -
Applied Research and Development Program Area Total	**$158.7**

Source: California Energy Commission.
*S11 funds are drawn from allocations in S1 – S10.

The proposed funding allocations for the *Applied Research and Development Program Area by Strategic Objective* provided in Table 8 were developed based on the priorities defined in the CPUC EPIC decision and the expected level of effort of applied research and development needed to fully address each of the specific strategic objectives. These funding levels are estimates and may change based on the number of successful responses received from competitive solicitation awards and the amount of leveraging of the EPIC funds from other parties that can be obtained by strategic objective. For S11, *Provide Cost Share for Federal Awards*,

up to 10 percent of the funding allocated for the applied research and development strategic objectives can be applied to providing cost share for these types of competitive federal awards.

Through this plan, the Energy Commission intends to issue solicitations in all strategic objectives. Proposed initiatives identified in this plan represent the full scope of possible awards. The Energy Commission may not issue solicitations or make awards in every initiative area if funding is inadequate, there is a lack of qualified applicants, or further analysis of market conditions indicates that an initiative is not currently a high priority or it is already adequately funded by other entities.

The following section describes each strategic objective under applied R&D and its associated proposed funding initiatives**.**

Energy Efficiency and Demand Response

S1 Strategic Objective: Develop Next-Generation End-Use Energy Efficiency Technologies and Strategies for the Building Sector

Table 9: Ratepayer Benefits Summary for Strategic Objective 1

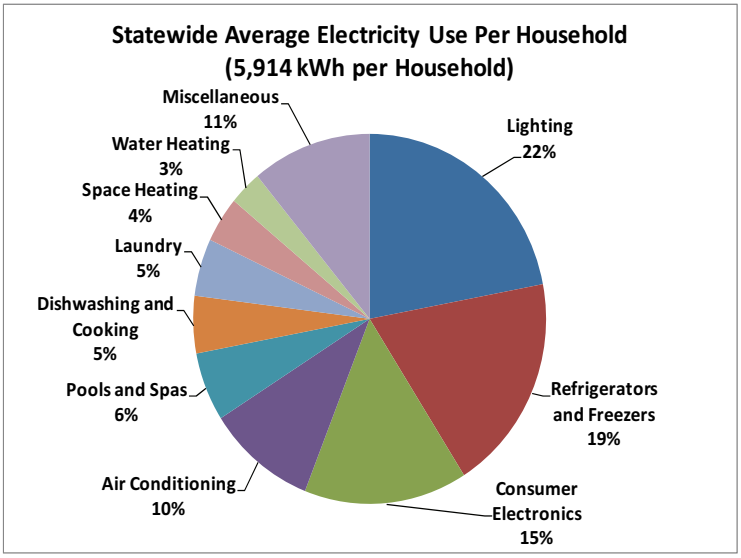
	Promote Greater Reliability	Lower Costs	Increased Safety	Societal Benefits	GHG emissions mitigation and adaptation	Lower emission vehicles/ transportation	Economic Development	Public Utilities Code Section 740.1	Public Utilities Code Section 8360
S1.1 Develop, Test, and Demonstrate Next-Generation Lighting Systems and Components.	X	X		X	X		X	X	
S1.2 Develop, Test, Demonstrate, and Integrate Equipment, Systems, and Components That Improve the Energy Efficiency of Existing and Advanced Heating, Ventilation, Air-Conditioning, and Refrigeration Systems.	X	X		X	X		X	X	
S1.3 Develop, Test, and Demonstrate Advanced Building Envelope Systems, Materials, and Components.	X	X		X	X		X	X	
S1.4 Investigate and Improve Understanding of Building Occupant Behavior and Related Consumer Choice Motivations to Increase and Sustain Energy Efficiency Improvements in Buildings.	X	X		X	X			X	
S1.5 Develop Cost-Effective Retrofit Strategies to Achieve Greater Energy Efficiency in Existing Residential and Nonresidential Buildings.	X	X		X	X		X	X	
S1.6 Reduce the Energy Use of Plug-Load Devices Through the Development of Products, Systems, and Controls, and Evaluation of Consumer Behavior That Affects Energy Use.	X	X		X	X		X	X	
S1.7 Develop and Evaluate Ideal Strategies to Improve Indoor Air Quality in Energy-Efficient Buildings.		X	X	X				X	
S1.8 Develop Cost-Effective Technologies and Approaches to Achieve California's Zero Net Energy Buildings Goals.	X	X		X	X		X	X	X

Source: California Energy Commission.

Electricity use in residential and commercial buildings accounts for about 69 percent of electricity consumed in California. The Energy Commission and the California Public Utilities Commission (CPUC) have adopted a goal of achieving zero net energy building standards by 2020 for homes and by 2030 for commercial buildings. Achieving these goals cost-effectively will require development and adoption of advanced building energy efficiency technologies and strategies beyond what is currently commercially available.[15]

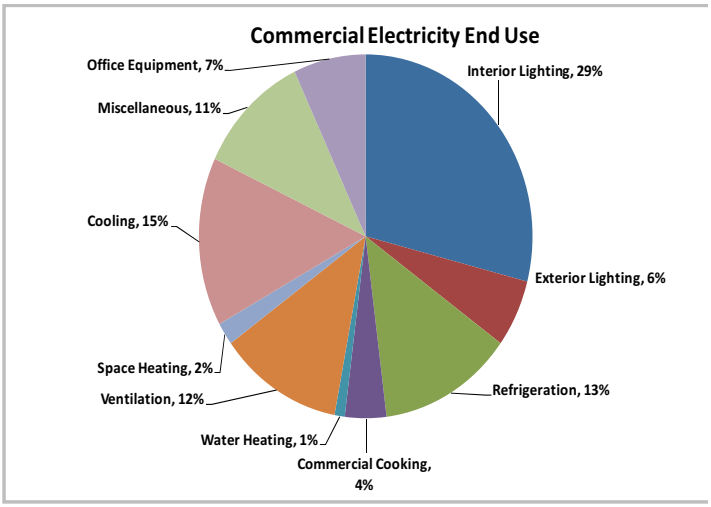
Most of the electricity used in residential and commercial buildings is for lighting, air conditioning, refrigerators, and consumer electronics.[16, 17] Significant strides have been made, but innovation is needed to increase the efficiency of lighting sources and their controls, cooling, ventilation, and refrigeration systems, and office electronics. This also includes integration of multiple technologies in whole buildings, due to the interactive effects that one technology can have on the other. For instance, reducing lighting load and improving the building envelope can affect air-conditioning and ventilation requirements. This

Figure 3: Statewide Average Residential Electricity Use



Source: *California Energy Efficiency Strategic Plan*, January 2011, page 10, http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/eesp/

Figure 4: Statewide Average Commercial Electricity Use



Source: California Commercial End Use Survey, March 2006, page 9, http://www.energy.ca.gov/2006publications/CEC-400-2006-005/CEC-400-2006-005.PDF

15 *California Energy Efficiency Strategic Plan.*

16 *California Residential Appliance Saturation Study*, 2010, www.energy.ca.gov/appliances/rass/.

17 *Commercial End Use Survey*, 2006.

comprehensive approach will be needed to achieve zero net energy use for new commercial buildings by 2030 and to achieve zero net energy or near zero net energy (with deep retrofits) for at least half of existing commercial buildings by 2030.[18]

Achieving the transformational goals for the residential and commercial sector contained in the *California Energy Efficiency Strategic Plan* will involve novel research that includes developing advanced energy efficiency technologies, services, and products; encouraging their use through utility incentive programs or building energy efficiency codes; and evaluating the behavior of energy users.

Applied research on energy efficiency technologies and strategies, as described in this section, can provide the foundational justification for future utility rebate and incentive programs. The Energy Commission's EPIC Program therefore plans to coordinate closely with the Emerging Technologies Coordinating Council (ETCC).[19] The ETCC will provide an opportunity for members to meet, collaborate, and exchange information on energy efficiency research and to provide a path for promising technologies to the marketplace. The ETCC focuses on identification, assessment, and rapid commercialization of energy-reducing technologies. The resulting products of the EPIC-funded applied research can help investor-owned utilities (IOUs) meet the energy efficiency goals set by the CPUC − namely that the IOU energy efficiency programs need to help California save 23 billion kilowatt hours (kWh) of electricity and 45 million therms of natural gas. This is the annualized equivalent of taking nearly 2 million cars off the road and lighting 3.4 million homes.[20] Ratepayers benefit with better, lower cost and more cost-efficient projects with validated savings.

Potential funding initiatives that were removed from consideration were those that had undetermined energy efficiency research benefits in advancing science and technology, required regulatory rate changes to be cost-effective, or could be considered in the future based on results of current research, roadmapping, or other IOU/CPUC-related activities. Examples of initiatives that were eliminated include projects that emphasized bioenergy improvements with no energy efficiency benefits, peak load-reducing technologies such as thermal energy storage that required special rate structures, and graywater reuse technologies.

Much of the research in this strategic objective will help provide the analysis and pilot activities to demonstrate the technical and economic feasibility of the technologies. Once this can be demonstrated, companies have an easier time securing private venture capital and other

18 *California Energy Efficiency Strategic Plan.*

19 Members of the ETCC include Pacific Gas and Electric, San Diego Gas & Electric, Southern California Gas, Southern California Edison, the Sacramento Municipal Utility District, the California Public Utilities Commission and the California Energy Commission.

20 Emerging Technology Coordinating Council, Hhttp://www.etcc-ca.com/about/11?task=viewH.

funding to further develop and improve the technology. The research in this strategic objective can also be used in developing future energy efficiency codes and standards, which is not research typically conducted by the private sector since it provides limited monetary benefit. Without the baseline data, testing, and analysis of existing equipment use and the potential benefits from higher efficiency equipment that this research will provide, it will be difficult to justify the continual strengthening and expansion of the building and appliance codes identified as needed by the *California Energy Efficiency Strategic Plan.*

S1.1 Proposed Funding Initiative: Develop, Test, and Demonstrate Next-Generation Lighting Systems and Components.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X							X

Source: California Energy Commission.

Issue: Lighting represents nearly 25 percent of California's electricity use and costs Californians about $10 billion each year. Though significant improvements have been made in lighting efficiency, continued innovation in energy-efficient lighting technologies and lighting systems is necessary to meet the *California Energy Efficiency Strategic Plan* goal of 60 to 80 percent reduction in electrical lighting energy consumption by 2020.[21] Similarly, light-emitting diodes (LEDs) offer benefits over compact fluorescents and other lighting technologies due to their high efficiency and more diverse design options but need innovative improvements to reduce cost and improve light spectrum quality and fixture design. In addition, natural daylight is underused in most buildings due to nonoptimized building design and lack of control systems to seamlessly integrate natural lighting with electric lighting. Furthermore, despite automatic occupancy controls many lights in existing buildings remain uncontrolled and stay on when they are not needed.

Purpose: This initiative will conduct research that promotes the development and implementation of new technologies and market applications to promote lighting systems and components with improved energy efficiency and performance. The focus will be to:

- Improve and develop whole lighting systems and components.

21 Hhttp://www.cpuc.ca.gov/NR/rdonlyres/A54B59C2-D571-440D-9477-3363726F573A/0/CAEnergyEfficiencyStrategicPlan_Jan2011.pdfH (see Chapter 13).

- Develop design and simulation tools that will encourage cost-effective daylighting,[22] as well as best retrofit strategies.
- Improve control systems to integrate electric lighting with natural lighting, coupled with optimal fixtures that lead to better overall light quality and consumer acceptance.
- Evaluate self-commissioning systems to compensate for installer inexperience, improve performance, and reduce installed costs.
- Conduct lab, bench-scale, and pilot programs to estimate energy savings and other benefits, identify technologies that are candidates for utility incentive programs, and inform future updates to building and appliance energy efficiency standards.
- Engage local experts and other stakeholders through public workshops to identify research priorities and needs associated with lighting-related R&D with the goal of providing cost-effective benefits to California ratepayers.

Stakeholders: Electric ratepayers who own and operate buildings and facilities, equipment manufacturers, lighting designers, researchers and utilities.

Background: Lighting offers significant opportunities for energy savings and peak demand reductions. Many new products that promise more efficient lighting, including LEDs, are beginning to enter the market, but additional work is needed to realize the full potential of these light sources. Increased interest, awareness, and emphasis on energy efficiency combined with rapid technological advances in LEDs and lighting controls systems could transform the lighting industry. This, in turn, will create opportunities for faster acceptance of new technologies that can accelerate reductions in energy consumption and greenhouse gas (GHG) emissions.

Lighting research focuses on advancing the Energy Commission and state energy policies by accelerating the development and commercialization of technologies through demonstration, outreach, education, and training. This initiative will complement past and current work on lighting and controls.

22 *Daylighting* is using natural light — for example, from direct sunlight or skylights — into a building to reduce electric lighting and saving energy.

S1.2 Proposed Funding Initiative: Develop, Test, Demonstrate, and Integrate Equipment, Systems, and Components That Improve the Energy Efficiency of Existing and Advanced Heating, Ventilation, Air-Conditioning, and Refrigeration Systems.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X							X

Source: California Energy Commission.

Issue: Heating, ventilating, and air-conditioning (HVAC) and refrigeration systems consume nearly 33 percent of California's electricity in the residential buildings sector and 42 percent in the commercial buildings sector.[23] It is not only a huge draw on the electric system, but the HVAC load also occurs during the summer peak demand period. Finding ways to reduce HVAC and refrigeration loads will be critical to reducing electrical demand, saving ratepayer money, reducing the need to run peaking units, and improving system reliability. Efficiency gains will reduce energy consumption and are key to achieving the state's zero net energy building goals.

Few HVAC and refrigeration systems perform at their maximum efficiency due to improper equipment sizing, undercommissioning, lack of recommissioning, changes in design and operating conditions, undetected faults, degradation, lack of maintenance, and refrigerant issues. Recent renovations of retail space have resulted in the addition of refrigeration and freezer units into space never designed to be a grocery store. This has resulted in operating inefficiencies of the HVAC units and increased energy use.

Purpose: This initiative will focus on the following areas:

- Improve the efficiency of existing HVAC and refrigeration systems.
- Develop advanced energy-efficient equipment and systems that are optimized for California climates.
- Optimize integration of HVAC and refrigeration systems.
- Develop fault detection and diagnostic tools and test protocols, especially for package and split-system air conditioners and refrigeration equipment to ensure continued system performance and energy efficiency over time.

23 *California Energy Efficiency Strategic Plan*, January 2011 Update. See also Figure 3.

- Develop simulation models, performance modeling rule sets to promote utility incentives and compliance credit for innovative systems, test protocols to detect refrigerant issues (for example, leakage, contamination, and flow restrictions), and appropriate design guides.
- Develop and implement pilot programs for candidate technologies.
- Engage local experts and other stakeholders through public workshops to identify research priorities and needs associated with HVAC and refrigeration-related research and development with the goal of providing cost-effective benefits to California ratepayers.

The research in this initiative endeavors to address barriers that lead to inappropriate equipment sizing with an emphasis on whole system integration that considers all components while also ensuring continued system performance and energy efficiency over time. These efforts could be accomplished by developing fault detection and diagnostic tools, test protocols, and new approaches to detecting and reducing refrigerant leakage, a source of GHG emissions.

This initiative will be coordinated with other ongoing CPUC/IOU activities/studies. This will ensure that the research and work scope will a) benefit and inform CPUC/IOU efficiency policy and b) be consistent with energy, monitoring and verification frameworks, standards, and the *California Energy Efficiency Strategic Plan*'s *HVAC Action Plan*.[24]

Stakeholders: Electric ratepayers who own and operate buildings, HVAC equipment manufacturers and contractors, engineers, building designers, academia, researchers and utilities.

Background: HVAC and refrigeration systems are among the largest consumers of electricity in residential and commercial buildings and are therefore one of the primary targets for reducing energy consumption. Reductions in HVAC energy consumption have also been targeted by the CPUC in its 2010-12 and 2013-14 IOU energy efficiency portfolio and are a component of utility incentive programs.[25] [26] The IOUs, HVAC designers and contractors, and regulators also need better and simpler simulation tools to help design and evaluate high efficiency systems, justify incentive levels, and develop and improve energy efficiency standards.

Past research focused on advanced evaporative air conditioners, radiant floor cooling, and under-floor air-distribution systems. For instance, research to evaluate the benefits of radiant cooling systems resulted in the adoption of this technology by several Wal-Mart stores located in hot, dry climates. A ceiling-mounted radiant cooling system for homes is under

24 HVAC Action Plan, http://www.cpuc.ca.gov/NR/rdonlyres/25B56CBE-7B79-41BC-B1C0-AE147F423B19/0/HVACActionPlan.pdf.

25 http://www.energy.ca.gov/2011_energypolicy/documents/2011-07-20_workshop/presentations/Cathy_Fogel_Current_Public_Goods_EE_Program_for_Existing_Buildings.pdf.

26 http://www.calmac.org/events/EE_and_MEO_2103-14_decision_166830.pdf.

development. Additional work is required to move these technologies to the next level and potentially integrate them with other HVAC systems such as thermal energy storage. This initiative will further develop and pilot test these technologies, improve their performance and cost-effectiveness, and move them closer to wide-scale deployment and commercialization.

There has also been promising research on the development of automated tools for fault detection and diagnostics. These tools can help building operators detect and address operating problems promptly and automatically reduce energy cost and waste. However, additional research is needed to improve validation and standardization of these tools for broader adoption by the building industry. Research is also needed to ensure sufficient validated data collection for a variety of HVAC systems and system faults to increase confidence in diagnostic protocol evaluation. This tool will help HVAC contractors and facility managers make appropriate decisions to ensure energy-efficient operations of equipment.

The areas to be investigated in this initiative were identified through public workshops, internal deliberative discussions with the Energy Commission's Building and Appliance Energy Efficiency rulemaking staff, and public comments on the draft EPIC investment plan.[27]

S1.3 Proposed Funding Initiative: Develop, Test, and Demonstrate Advanced Building Envelope Systems, Materials, and Components.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X							X

Issue: Building energy efficiency, durability, and habitability are strongly influenced by the building envelope, which consists of the structure's outer shell. Elements of the building envelope include doors, windows, skylights, roofs, walls, foundations and their constituent materials, and the overall envelope design in which the elements reside. Across the United States, 38 percent of residential building energy use is related to heating and cooling, and a large fraction of this is related to the building envelope.[28] New materials, manufacturing

27 August 2011 workshop: www.energy.ca.gov/research/notices/2011-08-31_workshop/presentations February 2012 workshop: www.energy.ca.gov/research/notices/2012-02-23_workshop/presentations and comments on the EPIC plan: www.energy.ca.gov/research/epic/documents/2012-09-27_workshop/comments

28 Hhttp://www.c2es.org/technology/factsheet/BuildingEnvelopeH.

techniques, and technologies for improving the performance of existing structures are becoming available.

These technologies and techniques show promise but often need further development and validation before they enter the market.[29] Simulation tools may lack the ability to model specific benefits of these new systems and will need enhancement to include characteristics of the new materials, components, and designs. For example, dynamic windows, which are electrically controllable to manage light transmittal, are now in an early stage of market deployment, but accurate simulation of the energy benefits of these windows will require further assessment of the window performance as well as further development of simulation tools.[30]

While lighting components are easily replaced and HVAC equipment is replaced every 20 years or so, envelope features and components often last for the life of the building. This makes these features disproportionately important in terms of energy use. Envelope features affect not only the energy consumption of a building, but the health and comfort of its occupants. Poorly placed windows can cause thermal discomfort and glare. Materials that emit air toxics can affect occupant health, with recent studies implicating building materials in air quality issues.[31] Even when buildings are well-designed and materials are carefully selected, improper construction methods can lead to air and water leakage that can affect occupant health and building efficiency and durability.[32]

More work is needed in this area because past research indicates that many new buildings do not perform as well as they could and often exhibit comfort, performance, and energy deficiencies from the first day.[33] Since the private sector will not do this research because there is generally no way of recouping the investment required, public investment is required.

Purpose: This initiative will conduct research to improve the performance of building envelope systems, materials, and components. The primary focus is to improve and develop cost-effective products, systems, and materials including whole-building designs, manufacturing techniques, and simulation tools to ease their successful entry into the market and to advise future building energy efficiency standards. The initiative will:

- Engage local experts and other stakeholders through public workshops to identify research priorities and needs associated with envelope-related R&D with the goal of providing cost-

29 Hhttp://www1.eere.energy.gov/buildings/envelope_rd.htmlH.

30 Hhttp://apps1.eere.energy.gov/buildings/energyplus/H.

31 Hhttp://homes.lbl.gov/content/hazard-assessment-chemical-air-contaminants-measured-residencesH.

32 Hhttp://www.energy.ca.gov/2007publications/CEC-500-2007-036/CEC-500-2007-036.PDFH.

33 *Efficiency Characteristics and Opportunities for New California Homes (ECO) - Final Project Report*, http://www.energy.ca.gov/publications/displayOneReport.php?pubNum=CEC-500-2012-062.

effective benefits to California ratepayers in the form of lower energy bills and healthier, more durable, and more comfortable residential and commercial structures.

- Identify needed improvements that can increase the energy efficiency of building envelope systems, materials, and components. This will be accomplished by using research and product developments discovered during assessments and targeting other ongoing complementary research.
- Evaluate new materials and components for building envelopes and evaluation of durability and energy performance. For example, infrared reflective pigments incorporated into wall paints may be able to reflect nearly half of the incident solar energy, potentially reducing cooling loads, but research is needed to validate their energy performance and durability.
- Assess the most effective ways to measure the performance of building envelopes and promote techniques that achieve high performance, including manufacturing processes.
- Develop and implement pilot programs for candidate technologies.

Managers in California IOU emerging technology programs have expressed support for this type of research and have proposed that some research activities be conducted in harsher climates in Southern California.

Stakeholders: Electric ratepayers who own and operate buildings and facilities, equipment manufacturers, engineers, building designers and developers, academia, and utilities.

Background: Research has been conducted to make buildings more efficient by promoting new envelope systems and other building components that are efficient, durable, and cost-effective. The results from past research were the basis for the initiatives in this section. Examples of past research include:

- Fenestration: Lawrence Berkeley National Laboratory's Windows and Facades test bed has looked at innovative ways to cut energy use in windows and window treatments. This has resulted in developing improved modeling and simulation tools. New types of windows that dramatically reduce infiltration are used in passive houses in Europe, but the high cost of these windows is a market barrier in the United States. Assessments of the benefit of these windows and development of manufacturing approaches to reduce their cost are needed to ease market entry.[34] Windows often allow water to leak inside walls, potentially leading to mold growth. Window improvements that eliminate this source of leakage need development and independent validation to enhance building durability and ensure that these products perform as claimed.[35] Further research is required to develop more robust

34 http://buildings.lbl.gov/.

35 Hhttp://www.energy.ca.gov/2007publications/CEC-500-2007-036/CEC-500-2007-036.PDFH.

daylight discomfort glare models to enable improvement in automated controls.[36] Interior shade products can reduce cooling loads and improve thermal comfort but are not as effective as exterior systems. Additional research is needed to promote integrated designs and create the demand for high-efficiency buildings.[37]

- Roofing and building envelope: Past research has resulted in developing innovative cool roof materials. New roofing materials include coatings that increase reflectivity and emissivity[38] and keep structures cooler during hot, sunny summer months. Efforts are also underway to integrate solar photovoltaic (PV) cells more effectively into roofing materials.[39] Other envelope improvements, such as insulation at the roof plane and sealed attics, are also being tested and need rigorous validation. Retrofit technologies like techniques for sealing existing building envelopes with adhesive mist show great promise, but research is needed to monitor and verify energy and cost savings.
- Building manufacturing: Improvements in manufacturing processes, such as use of in-shop manufacturing and quality control for entire wall sections, can reduce waste and construction defects that typically plague site-built structures. The benefits of these techniques need assessment and possible credit in building standards. All of these new building techniques, materials, and components require updated simulation tools to provide accurate information to designers, engineers, and standards developers.

36 High Performance Building Façade Solutions: http://gaia.lbl.gov/btech/papers/4583.pdf.

37 Ibid.

38 Emissivity refers to a material's ability to release absorbed heat. In warm and sunny climates, highly emissive roof products can help reduce the cooling load on a building by releasing heat absorbed from the sun.

39 Hhttp://heatisland.lbl.gov/coolscience/cool-science-cool-roofsH.

S1.4 Proposed Funding Initiative: Investigate and Improve Understanding of Building Occupant Behavior and Related Consumer Choice Motivations to Increase and Sustain Energy Efficiency Improvements in Buildings

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X							X

Issue: Energy used in buildings varies widely depending on occupant behavior. Energy use is also significantly affected by consumer purchasing decisions regarding appliances and electrical devices. Understanding building occupant attitudes, patterns, and motivations that affect energy use behaviors is critical to identifying and tailoring strategies that will result in persistent energy savings. Issues include:

- Types of technologies and information needed by particular individuals and groups that will address their needs, values, and motivations.
- How to effectively identify target customers for efficiency and demand response program participation and how to effectively develop marketing, incentive, and education programs for customer segments that will produce measurable energy savings.
- How to design technology to provide useful and actionable energy information.
- How to measure accurately the effects of these strategies with the goal of significantly affecting awareness, concerns, and actions related to energy use.
- How to quantify and correlate nonenergy benefits and their motivational effect on energy-related consumer choices.

Purpose: This initiative will conduct research to better understand the factors that motivate customers and tenants to make energy-efficient equipment purchases and operate buildings in the most energy-efficient manner. The research will address the role of consumer choice and operational behavior in influencing the way equipment is designed and operated. It will also address how privately and publicly supported energy efficiency programs can be tailored and improved to expand participation in target audiences. Potential research areas include:

- Determining the types of energy information that motivates different types of customers – using demographic, geographic, and other characteristics – to make energy-efficient choices with respect to purchasing devices and equipment and operating energy using appliances or devices in homes and workplaces.

- Answering key questions such as how, where, and when such information should be provided and/or displayed.
- Considering how the information should be framed and to what degree and in what situations energy efficiency should be automated versus controlled by end users.
- Analyzing smart technologies available on the market that can program and automate energy using devices such that energy use can be reliably predicted for planning public or utility program initiatives.
- Analyzing the persistence of the effects of behavioral energy efficiency programs and providing feedback and understanding of the real potential for behavior-based programs.[40]
- Testing and determining the most effective ways to measure responses to energy information.
- Determining how best to collect, disaggregate, and interpret energy data provided by building occupants and owners, smart meters and utility companies.
- Demonstrating technologies and promoting market education and adoption.
- Examining the effect of different information delivery channels or methods.
- Reviewing best practices in behavior change that could be applied to ratepayer funded clean energy training programs.

This initiative will be coordinated with other on-going behavior activities/studies by the CPUC, the California Air Resources Board (ARB), and the IOUs. This coordination will ensure that the research and work scope is not duplicative and will provide mutual benefits that will inform each respective group's efficiency policy. The coordination will also ensure consistency of energy monitoring and verification frameworks, standards, and other requirements.

Stakeholders: Electric ratepayers who own, operate or occupy buildings and facilities, equipment manufacturers, engineers, building designers and developers, academia, governmental agencies, and utilities.

Background: A 2008 study conducted by the National Buildings Institute on the energy performance of Leadership in Energy and Environments Design commercial buildings revealed that many of these buildings (built to similar specifications) have not performed to the energy efficiency targets that were expected. The study concluded that building energy performance is not determined solely by the technologies included in the design, and that tenant/occupant choices and general building operations can either substantially improve or degrade building energy performance. In the residential sector, some studies have shown that nearly identical

40 This research would support the CPUC's recent decision requiring IOUs to engage 5perecent of households in their service areas in energy efficiency programs.

housing units occupied by demographically similar families have reported large (for example, 200-300 percent) variations in energy use (Lutzenhiser 1993). There are also studies that show increased energy use after building energy retrofits, exactly the opposite of what one would expect (Andres and Loudermilk 2010).

The need and importance of operational behavior research associated with energy efficiency has been repeatedly raised at workshops and public meetings sponsored by the Energy Commission, including those for the EPIC Program. The consensus is that energy-related operational behavior and consumer choices are areas with significant knowledge gaps that need to be addressed. Better understanding is needed to realize energy savings through providing energy information and feedback. These decisions affect how technology is designed to provide what information, how utility incentive and demand response programs are created, and how building designs incorporate automatic versus manual control in the energy-related systems. Additionally, energy-related tenant operational behavior and consumer motivations to consider energy when making purchases are the key subjects discussed at the annual Behavior Energy and Climate Change conference.[41] There is growing recognition of the importance of this topic as evidenced by the number of abstracts submitted for the conference each year.

Based on the early phase of a current study at Stanford University, "Large-Scale Energy Reduction Through Sensors, Feedback, and Information Technology," energy cost by itself is not a strong enough motivation to change behavior. Preliminary projections indicate that intervention strategies that create energy awareness can result in energy reductions ranging from 5 percent to 30 percent. However, the study duration period is not long enough to measure persistent effects, and in some cases, sample sizes are small. Nonetheless, the research will provide valuable insights into what may be effective energy-conserving strategies with respect to technology, design, social and marketing incentives, identifying responsive utility customers, and information framing. The research is scheduled to be completed in October 2013.

Some utility companies and private sector consulting firms that are studying how to market and design utility incentive programs are doing small-scale energy behavioral research, but significant knowledge gaps remain about how to influence behaviors in ways that produce persistent savings and how to accurately measure those savings.

New technologies such as whole house power meters, smart appliances, and home area networks are coming on the market, but it is unclear how effective these technologies are in achieving continuing energy savings due to a lack of statistically significant studies that clearly establish the links between information, customs, habits, and the correct operation of devices. Funding for larger and longer duration studies is needed to determine with confidence what

41 http://beccconference.org/.

persistent energy-related behavior change is achieved using different intervention strategies. Review of the literature indicates that there are few such studies that have been done to date.

S1.5 Proposed Funding Initiative: Develop Cost-Effective Retrofit Strategies to Achieve Greater Energy Efficiency in Existing Residential and Nonresidential Buildings.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X							X

Issue: Nearly 60 percent of California's housing stock (and a comparable percentage of the state's commercial building stock) was built before the establishment of California's first Building Energy Efficiency Standards in 1978.[42] Accordingly, substantial energy efficiency improvements are needed in most of California's existing buildings, particularly in multifamily residential and small and mid-size commercial buildings. However, many market and cost barriers prevent energy retrofits to residential and commercial buildings. Foremost are the economic payback of energy retrofits, longevity of home ownership, and the split incentives between renters and building owners (since in many cases renters pay utility bills and building owners do not). Additional barriers include:

- Lack of knowledge by building owners and financial decision makers of the attributes of energy-efficient buildings.
- Knowledge of how to obtain a higher performance building.
- Knowing what resources (tools, models, and entities) are available to help building owners.
- Knowing how to assess cost-effectiveness of building retrofits, and how to obtain low-cost financing for retrofits.

Purpose: This initiative will develop new technologies and approaches for cost-effective energy efficiency retrofits in existing buildings in IOU territories. Proposed research includes:

- Developing a roadmap for maximizing cost-effective energy efficiency retrofits in existing buildings. The roadmap will consider the Assembly Bill 758 (Skinner, Chapter 470, Statutes of 2009) Scoping Plan and subsequent action plans, including robust stakeholder input and the guiding principles established by the CPUC and Energy Commission.

42 www.energy.ca.gov/ab758/documents/AB_758_Technical_Support_Contract_Scope_of_Work.pdf.

- Identifying and piloting innovative technologies and approaches to bring energy efficiency retrofits solutions to low-income residential builders/owners and the multifamily market.
- Developing and demonstrating an integrated suite of cost-effective, advanced energy efficiency measures, tools, models, and strategies for enabling best practices in retrofit construction. This includes identifying the most cost-effective package of advanced heating, cooling, and ventilation, lighting, plug-load efficiency strategies, building envelopes, domestic hot water systems, building controls, and performance technologies for use in existing buildings in California climates. This includes use of simplified, low-cost tools that use satellite imaging rather than onsite audits, such as the Building Energy Asset Rating System (BEARS), to reduce the cost of assessments.
- Evaluating current issues that underlie the lack of available energy performance information for decision makers in the building retrofit marketplace.
- Investigating and collaborating with others to institute common data collection and sharing protocols that can be instituted in all public and ratepayer-funded RD&D and other incentive and evaluation programs, to provide this much-needed performance information to all market actors.
- Investigating the role of consumer behavior, particularly in multifamily buildings, to develop technologies and approaches for cost-effective strategies in the retrofit market.

This initiative will coordinate with ongoing activities and studies by the CPUC, IOUs, and the Energy Commission related to AB 758 implementation and whole building retrofits.

Stakeholders: Electric ratepayers who own and operate buildings and facilities, equipment manufacturers, engineers, building designers, developers, contractors and consultants, academia, governmental agencies, utilities, national labs.

Background: Existing building retrofits have occurred haphazardly. Utility rebate programs have focused on specific energy technologies rather than whole-building approaches and participation in those programs is limited. Whole-building energy audit programs typically target specific sectors or to organizations with a desire to upgrade or renovate. Often, energy renovations require a champion to push for improvements and identify energy and nonenergy benefits (for example, improved employee, or student performance). Split incentives can deter any energy improvements since building owners often do not pay utility bills or reap the benefits from retrofits.

S1.6 Proposed Funding Initiative: Reduce the Energy Use of Plug-Load Devices Through the Development of Products, Systems, and Controls, and Evaluation of Consumer Behavior That Affects Energy Use.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X							X

Issue: Plug loads, devices that plug into electrical outlets, are becoming an increasingly large share of residential and commercial building energy load. If not controlled, the current plug load trajectory could affect meeting the ZNE buildings goals in California by 2020 and is estimated to be about 40 percent of the energy use of a ZNE building.[43] [44] Current barriers include lack of controls, high-energy use of plug load devices, low efficiency, and a wide range of products. As a result, more comprehensive and ambitious plug-load research, efficiency improvements, and policy action resulting in new Title 20 standards are needed. There are significant building design and operation issues with regard to plug loads. Behavior and occupancy are also a significant influence.[45]

Purpose: This initiative will advance the development and deployment of more efficient consumer and office electronics. Potential research includes:

- Improve and develop efficiency improvements in existing and future plug-load devices while also including the integration of smart controls.
- Advise future Title 20 appliance standards, as applicable.
- Address behavioral and other issues.
- Develop and implement pilot programs for candidate technologies.
- Engage local experts and other stakeholders through public workshops to identify research priorities and needs associated with plug load-related research and development with the goal of providing cost-effective benefits to California ratepayers.

43 http://calplug.uci.edu/index.php/7-main.

44 Kaneda, Jacobson, Rumsey, "Plug Load Reduction: The Next Big Hurdle for Net Zero Energy Building Design," http://eec.ucdavis.edu/ACEEE/2010/data/papers/2196.pdf.

45 Ibid.

The efforts will complement and coordinate with other past and current research being undertaken by UC Irvine, national laboratories, and others. This research is anticipated to be supported by consumer/business equipment industry, utilities, and standard setting groups.

Stakeholders: Electric ratepayers who own and operate plug load devices, equipment manufacturers, engineers, building designers, developers, contractors and consultants, academia, governmental agencies, utilities, national labs and researchers.

Background: Plug loads are not traditional appliances and contain internal or external AC-DC power supplies. Energy use in the residential and commercial sectors in California for plug loads is one of the fastest growing energy loads. For instance, the average house that contained only four or five plug load devices 20 years ago now has as many as 50.[46] Current estimates indicate that plug loads are contributing about 15-20 percent of residential and 10-15 percent commercial electrical use, and this use could nearly double by 2030.[47] Recent estimates by the U.S. DOE have put residential plug load, without intervention, at 40 percent by 2035. At this pace, plug load energy use will prevent achievement of the state's zero net-zero energy building goals.[48]

Past research focused on external power supplies, office electronics, battery chargers, flat-screen televisions, home stereo/audio systems, 24/7 kiosks (for example, ATMs) and computers. The Energy Commission's plug load research to date has been very successful and is projected to result in annual savings of more than $1.2 billion through adoption of three Title 20 Standards.[49] The UC Irvine's CalPlug Center is performing research on set-top boxes due to the potential for large savings.[50] Preliminary estimates by UC Irvine show that California may be able to save about $400 million per year through set-top box improvements. This initiative will continue research into other plug load areas such as improving computer efficiency, improving the efficiency of small server rooms, understanding smart user controls, and how to create a

46 http://viewer.epaperflip.com/Viewer.aspx?docid=bfddb00c-6c9a-4169-befe-a06101208516#?page=16.

47 U.S. DOE Annual Energy Outlook, 2008.

48 Brown, Rittleman, Parker & Homan, *Appliances, Lighting, Electronics, and Miscellaneous Equipment Electricity Use in New Homes*. 2006.

49 Battery charger: www.energy.ca.gov/appliances/battery_chargers/documents/2010-10-11_workshop/2010-10-11_Battery_Charger_Title_20_CASE_Report_v2-2-2.pdf.
Televisions: www.energy.ca.gov/appliances/2008rulemaking/documents/2008-04-01_workshop/2008-04-04_Pacific_Gas_+_Electric_Televisions_CASE_study.pdf.
External power supply: www.energy.ca.gov/appliances/2004rulemaking/documents/case_studies/CASE_Power_Supplies.pdf.

50 www.nrdc.org/energy/files/settopboxes.pdf.

personal user energy footprint based on the collection of data from a variety of plug-load end uses collected in smart meters.

S1.7 Proposed Funding Initiative: Develop and Evaluate Ideal Strategies to Improve Indoor Air Quality in Energy-Efficient Buildings

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X							X

Issue: Indoor air pollution in California – not including tobacco smoke – has been attributed to around $11 billion per year in adverse health impacts with another $9 billion attributed to lost productivity in office workers and teachers. The increased efficiency of new and existing buildings is resulting in tighter buildings that reduce air infiltration. As a result, indoor air quality is deteriorating**.** Use of new construction materials and products and increased use of recycled materials may result in increases of unknown emissions (such as semivolatile organic compounds). Research is needed to identify the resulting indoor air quality and public health consequences and develop cost-effective mitigation measures.

Purpose: This initiative will focus on research to characterize indoor air quality and develop cost- and energy-efficient air quality improvement methods.

Stakeholders: Electric ratepayers who own and operate buildings and facilities, engineers, building designers, developers, contractors and consultants, academia, governmental agencies, utilities, and national labs.

Background: To help meet AB 32 goals, the Energy Commission is working with the CPUC, the ARB, and various stakeholders to implement the *California Energy Efficiency Strategic Plan*. One of the goals in the plan is to strengthen and expand building and appliance codes and standards. The increased efficiency of new and existing buildings is resulting in tighter buildings that reduce air infiltration. Past research was guided by the *2002 Energy-Related Indoor Environmental Quality Research: A Priority Agenda* and has resulted in several landmark studies of indoor environmental quality and related factors in California. These include studies of new residential buildings, small and medium commercial buildings, and pollutant emissions from office equipment. Current studies are looking at retrofits of low-income apartments, exposure from unvented combustion appliances, and healthy zero-energy buildings. In addition, studies of building heating, ventilating, and air conditioning (HVAC) and air leakage that are pertinent to indoor environmental quality have been conducted. *Indoor Environmental Quality: Research Roadmap 2012-2030: Energy-Related Priorities* has been developed to guide future research.

ARB sponsors research on indoor air quality covering topics such as indoor and personal exposure, indoor-outdoor relationships, and toxic air contaminants. ARB has funded large indoor air quality field studies in homes and schools, as well as studies on emissions from indoor sources, building ventilation, and air cleaners.

The U.S. Environmental Protection Agency (U.S. EPA) Indoor Air Quality research focuses on improving techniques to measure and model emissions of indoor chemical contaminants present in a variety of structures such as schools, office buildings, and homes and investigates a variety of approaches to ameliorate mold problems in residences and office buildings. In the late 1990s, the U.S. EPA completed the landmark Building Assessment, Survey, and Evaluation (BASE) study to determine the typical concentration distributions of a number of chemicals found in a representative sample of office buildings in the United States to correlate these pollutant levels with building parameters and occupant activities and symptoms. The U.S. DOE's indoor air quality research and development focuses on developing new ventilation strategies that simultaneously improve indoor air quality and reduce the energy impact of increased ventilation.

S1.8 Proposed Funding Initiative: Develop Cost-Effective Technologies and Approaches to Achieve California's Zero Net Energy Buildings Goals

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X							X

Issue: Existing studies are underway by the IOUs to develop ZNE roadmaps that identify barriers and cost-effective strategies and technologies for the most promising building types. However, there has been little focus on ZNE building strategies for multifamily and small commercial buildings. Owners of these types of buildings have very little incentive to achieve ZNE when they do not pay utility bills. Because ZNE buildings have noticeably higher first costs than traditional building designs, marketing and consumer education has been unable to encourage widespread acceptance of ZNE as a high-priority goal despite subsidies, tax incentives, and other financial incentives.

On the technical side, there has been little analysis correlating climate zones and the most appropriate building types with the most potential for ZNE application. Some single or combined emerging technologies have potential to maximize energy efficiency and reduce overall building and life-cycle costs. Examples include dynamic windows, radiant heating and cooling, direct current lighting, and advanced innovative applications of thermal energy storage. However, these strategies need to be integrated into whole buildings and their

performance measured on a pilot scale. Another technical barrier is that many existing newly planned buildings are not suitable for onsite electricity generation or solar hot water systems due to orientation, shading, and other factors. To meet the energy needs of buildings with renewable energy, builders and designers must apply holistic design principles and take advantage of naturally occurring assets, such as passive solar orientation, natural ventilation, daylighting, thermal mass, and nighttime cooling along with maximizing energy efficiency. Climate-specific technologies and design practices also need to be developed to account for the wide variations in heating and cooling needs based on climate zone.

Purpose: This initiative will coordinate and complement existing studies by the CPUC and IOUs and activities to reach ZNE building goals cost-effectively. Potential research includes:

- An assessment and review of current and past ratepayer-funded studies, roadmaps, technical potential studies, and barriers identification studies to determine research gaps that still need analysis to support ZNE targets consistent with the *California Energy Efficiency Strategic Plan*. Once the assessment is completed, develop a solicitation to address these research gaps.
- A review of the technical potential of ZNE in both residential and nonresidential buildings in climate zones not currently being analyzed by IOUs and the appropriate cost-effective mix of measures. This activity will be coordinated with IOUs in order to be consistent in identifying energy use index targets for several building types.
- Evaluation of alternative business models and definitions for achieving ZNE or near-ZNE building goals. This can include an assessment of the economic breakpoints by climate zone and by different ZNE definitions to get to ZNE buildings. For instance, in some climate zones it may not be economically feasible to get entirely to ZNE, but it may be possible to achieve 80 percent of the potential.
- Integrating pilot-scale evaluation of measures most suitable for cost-effective deployment of ZNE buildings.

Stakeholders: Electric ratepayers who plan to build ZNE buildings, equipment manufacturers, engineers, building designers, developers, contractors and consultants, academia, governmental agencies, utilities and national labs.

Background: The *California Energy Efficiency Strategic Plan* and the Energy Commission's *Integrated Energy Policy Report* have established ZNE goals for residential and commercial new and retrofit construction.[51, 52] The CPUC has authorized several studies with Pacific Gas & Electric Company (PG&E) with the objective of establishing a framework for ZNE research that

51 *California Energy Efficiency Strategic Plan*, January 2011 Update, p. 11.

52 *2011 Integrated Energy Policy Report*, p. 8.

includes identifying technical potential, performing market assessments of drivers and barriers , identifying research needs, and developing a roadmap for new construction.[53] This initiative will build on the results of this work and some of the work listed below to achieve the ZNE goals.

- San Diego County's research project "ZNE Affordable Multifamily Housing" demonstrated that, with motivated local agencies, progressive developers, and a combination low-income tax credits, state rebates, and additional debt leveraged from energy cost savings, developers can fully cover the first cost of constructing a ZNE building. Thus ZNE or near ZNE is achievable in low-income multifamily buildings. This project also demonstrated that per-unit cost premiums could be minimized by using innovative integrated design principles and establishing clear project goals. The two apartment complexes that were the focus of the project generated almost as much energy (90 percent or more) as they drew from the electric grid. More work is necessary to replicate these types of results and overcome barriers in different climate zones and local jurisdictions.
- In the project "Commercializing Zero Energy New Home Communities" (2010), the goals were to define innovative and cost-effective approaches in the areas of PV systems, energy efficiency product selection, and new home design and construction standards. Three homebuilders built more than 270 ZNE homes in four demonstration communities; one of the buildings was a 46-unit multifamily building. The single-family homes exceeded existing Title 24 energy efficiency standards by 35 percent, and energy costs were 60 percent to 70 percent lower than comparably built non-ZNE housing. According to the builder, the premium for the homes with ZNE was minimal, and the ZNE homes sold much faster than similar homes without PV systems.
- In a larger-scale energy efficiency project, *Energy-Efficient Community Development in California: Chula Vista* (2008), results of modeling 40 building types with various optimizations of energy-efficient technologies were combined with renewables and some multibuilding heating and cooling strategies. The project models demonstrated the potential to reduce energy use by up to 43 percent and peak demand by 45 percent as compared to the Title 24-compliant project/development in place at the time. The modeling to determine the best combination of market-feasible technologies indicates that these technologies are building-specific. Results of the financial, business, and policy analysis show that communities need new public and private sector management models to address barriers that currently impede adopting these building technologies and site features by the building industry. In-depth study and the development of solutions to these barriers are needed in future research.

53 www.pge.com/.../b2b/purchasing/bidopportunities/ZNE_Pilot_Program.doc.

- Habitat for Humanity has built several ZNE, or near ZNE, single-family homes that have demonstrated the potential to build affordable ZNE homes for low-income families. Monitoring persistence of savings to document benefits over time is needed.

Though there has been interest in ZNE building design, there is little information on the best approaches for meeting the ZNE goals of the different building sectors and types by climate zones. Due to this, very few designers, builders, or contractors have the expertise or experience to construct ZNE buildings.

S2 Strategic Objective: Develop New Technologies and Applications That Enable Cost-Beneficial Customer-Side-of-the-Meter Energy Choices.

Table 10: Ratepayer Benefits Summary for Strategic Objective 2

	Promote Greater Reliability	Lower Costs	Increased Safety	Societal Benefits	GHG emissions mitigation and adaptation	Lower emission vehicles/ transportation	Economic Development	Public Utilities Code Section 740.1	Public Utilities Code Section 8360
S2.1 Develop Cost-Effective Metering and Telemetry to Allow Customers With Demand Response, Distributed Generation, Plug In Electric Vehicles, and Energy Storage to Participate in California ISO Markets and/or Provide Grid Services.	x	x		x	x	x		x	x
S2.2 Develop Demand Response Technologies and Strategies to Allow Customers to Participate in Ancillary Service Markets and/or in Dynamic Price and Reliability-Based DR Programs and Market Transactions in Retail and Wholesale Markets.	x	x		x	x		x	x	x
S2.3 Demonstrate and Evaluate the Integration of Distributed Energy Resources, Including Storage and Demand Response, at the Community Scale and in Microgrids.	x	x		x	x	x	x	x	x
S2.4 Develop and Test Novel Technologies, Strategies, and Applications That Improve the Business Case for Customer-Side Dispatchable Distributed Resources and/or Expansion of Demand Response Capabilities.	x	x		x		x	x	x	x

Source: California Energy Commission

Customer participation in dynamic pricing and other programs allows them to reduce their electricity demand and generate new income streams. Customer participation delivers value

and cost savings in multiple ways. Customers who participate in these dynamic pricing programs are rewarded for being willing to reduce their individual energy demand on critical days and during times the utility grid is reaching its peak demand limitations. Additionally, customers who own distributed resources including demand response (DR), distributed storage, distributed generation (DG), and plug-in electric vehicles (PEVs) will have a new revenue stream by providing grid support such as ancillary services and voltage stability to address intermittent generation resources. In addition, greater customer participation in these programs will help utilities and grid operators reduce peak demand and integrate intermittent renewables while providing the benefits of a more reliable grid.

The following initiatives will address barriers and advance the technologies, applications, and strategies to enable and encourage customer-owned resources to participate in energy market programs that provide demand-side management.

S2.1 Proposed Funding Initiative: Develop Cost-Effective Metering and Telemetry to Allow Customers With Demand Response, Distributed Generation, Plug-in Electric Vehicles, and Energy Storage to Participate in California ISO Markets and/or Provide Grid Services.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X				X			X

Issue: This research addresses barriers to cost-effective metering and telemetry. Telemetry refers to automatic measurement and transmission of data by wire, radio, or other means from remote sources to a distant receiver for recording and analysis. The cost of telemetry is a major barrier to the expanded use of automated demand response, distributed renewables, combined heat and power (CHP) generation, electric vehicles and other distributed energy resources. This barrier makes it very difficult for these technologies to participate in California ISO programs for ancillary services, especially frequency regulation, because of the current need for the high fidelity metering systems. Lowering these costs will increase the integration of systems that can provide ancillary services.

Purpose: This initiative aims to reduce the cost of communication and telemetry technologies and improve automation to allow more electricity customers to participate in dynamic ancillary services markets. This will ease the addition of more renewable generation to the grid to help meet Renewables Portfolio Standard (RPS) goals and Governor Brown's Clean Energy Jobs Plan goal of 6,500 MW of additional CHP by 2030. Other DG, such as biomass, energy storage, and DR technologies, may be able to participate in dynamic ancillary services markets and/or provide grid services with cost-effective metering and telemetry.

Areas of research include:

- Developing less-expensive telemetry technologies.
- Researching best practices and data requirements for ancillary services markets used by other independent system operators.
- Exploring ways to reduce the cost of metering and telemetry for automated demand response, electric vehicles, small generators of renewable energy and CHP.
- Exploring ways to lower the costs of data verification, and determining timescales and granularity required by the distribution and transmission system to provide grid operators with transparency and visibility of customer-side-of the meter resources.

Based on staff's review of the initial drafts and the information provided at public workshops sponsored by the IOUs for the proposed EPIC investment plans, the utilities identified plans for demonstration and deployment activities making greater use of both utility owned and customer owned distributed energy resources (DER) to supply grid support and ancillary services. As an example, San Diego Gas & Electric Company (SDG&E) proposes demonstrations of DER to provide services. PG&E is also proposing demonstrations of DER. Coordination of these IOU planned activities with the research under this initiative will enhance the results and ensure that activities are not duplicated.

Stakeholders: Ratepayers who have DER, system operators, and utilities.

Background: Alternative metering and telemetry systems protocols to the current systems required by the California ISO are developed, operating in other areas and are being enhanced through other stakeholder working groups and do not require EPIC funding. The commercial availability of the Open Automated Demand Response (OpenADR) and SEP 2.0 protocols will allow controls to make greater use of web-based internet connectivity. Web-based energy information systems have been demonstrated. These systems use the internet as an inexpensive communications platform to transfer secure data quickly and reliably. These systems can also track performance in DR events and help the customer see utility bill savings.

There has been excellent collaboration between control companies, utilities, and standards groups in adopting OpenADR and SEP 2.0. More research is needed to reduce telemetry costs. This research has drawn only limited funding from the U.S. DOE, but its role is growing.

The private sector has not developed lower-cost telemetry so far, as the California ISO requires essentially continuous two-way communications, especially for frequency regulation, and the market for this type of metering and telemetry is small.

S2.2 Proposed Funding Initiative: Develop Demand Response Technologies and Strategies to Allow Customers to Participate in Ancillary Service Markets and/or in Dynamic Price and Reliability-Based DR Programs and Market Transactions in Retail and Wholesale Markets

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations/ Market Design	Generation	Transmission/ Distribution	Demand – side Management
X				X			X

Issue: As renewable generation adoption accelerates, resources with intermittent and variable output will affect grid stability and increase the need for ancillary services.

DR can provide support of the grid by both lowering the peak demand during critical times and a variety of ancillary services to the grid operators. DR can be provided by residential, commercial, and industrial customers. Energy storage can supply ancillary services much the same as traditional generation, but current energy storage systems are significantly more expensive than generation alternatives. Based on experience gained over the last decade on utility and third party managed DR programs, DR services can provide many of the capabilities of energy storage, however, not as fast as classical energy storage systems. Vehicle-to-grid capabilities for plug-in electric vehicles (PEV) can function like energy storage, but it is limited in capacity. DR, when combined with either traditional energy storage or vehicle-to-grid, can provide cost-effective ancillary services. A set of tools is needed to help combine DR with other DER such as PEVs and other energy storage to enable customers to participate in ancillary services markets and/or in dynamic price and reliability-based DR Programs.

Purpose: Expanding the use of DR by developing a set of tools to help combine DR with other DER, such as PEVs and other energy storage, will enable customers with these resources to participate in ancillary services markets. This will also help residential, commercial, and industrial customers to participate in future dynamic pricing programs for both peak load reduction and ancillary services. This research will enhance grid flexibility and cost-effectiveness and create new revenue streams for end-users through participation in IOU dynamic pricing programs and California ISO markets. Interoperable tools and information systems will allow residential, commercial, and industrial building owners and operators to understand DR technologies and to reduce their electric bills, enable greater use of renewables, and shift peak demand.

Possible activities under this initiative will:

- Develop benchmarking and simulation tools and analysis platforms for DR strategies.

- Allow information from DR and DER (storage and PEVs) to be aggregated and dispatched in larger consolidated systems like a grid-scale battery to provide ancillary services.
- Explore use of real-time energy measurement, cost analysis, and modeling to improve customer economics and minimize bills.
- Evaluate the economic and other benefits to electric ratepayers.

Stakeholders: Ratepayers with DR, storage, PEVs or other DER; grid operators, and utilities.

Background: New technologies and operating practices are constantly developing on the distribution system in response to increasing penetration of renewable energy generation. There is a need for coordination and research to maximize end customer participation in utility dynamic rates and California ISO markets for ancillary services.

S2.3 Proposed Funding Initiative: Demonstrate and Evaluate the Integration of Distributed Energy Resources, Including Storage and Demand Response, at the Community Scale and in Microgrids.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X				X			X

Issue: Renewable generation will be a key component of energy-smart communities. Renewable generation tends to be more variable and intermittent, and does not have the system inertia for grid stabilization provided by conventional generation. This has increased the need for ancillary services, such as providing reactive power and voltage and frequency regulation. Energy storage can provide these services for energy-smart communities to deploy more renewable generation and stabilize the grid. AutoDR can also provide services to these communities that are responsive, timely and cost effective.

The high cost of most distributed energy storage systems is a primary barrier to market adoption. In addition, the required characteristics of energy storage systems vary between clean energy resources when used for peak demand shifting. For example, peak generation from solar resources needs to be shifted only a few hours to coincide with peak demand times. Wind energy, however, typically peaks at night and must be shifted further in time to match peak demand. Energy storage and AutoDR may provide the technological solutions to provide peak shaving. Furthermore, energy storage can be strategically deployed in energy-smart communities to maximize system reliability and provide voltage and frequency regulation where needed.

Purpose: This initiative will develop and evaluate the integration of energy storage systems, AutoDR, and DG applications within energy-smart communities to mitigate intermittency, increase the value of distributed renewable energy generation, and offset peak demand. Promising electric, thermal, and mechanical energy storage designs will be evaluated for their potential to mitigate the intermittency impacts of renewable energy generation and provide additional ancillary services in distributed settings. AutoDR, CHP and other distributed resources will be evaluated for their potential to mitigate the intermittency impacts of renewable energy generation and provide additional ancillary services in distributed settings. These evaluations will include the advantages and disadvantages of distributed electric storage systems at different sizes, scales, and locations and configurations, the combination of AutoDR and energy storage as a lower costs system, the use of distributed generation systems such as CHP to stabilize the local grid, and other technology combinations to provide energy smart communities and microgrids the services they need.

EPIC investment will support the integration of electric storage technologies with other system components such as inverters, electric vehicle chargers, and other DER. This will improve DG performance and interoperability with smart grid components and will decrease energy storage costs.

This initiative will also advance thermal energy storage systems to increase the ability to cost-effectively shift the demand profile of buildings within energy-smart communities and maximize the economic benefits of onsite electricity generation.

Stakeholders: Ratepayers due to greater renewables on the distribution grid, including ratepayer-owned renewable generation; utilities, and distribution grid operators.

Background: The National Renewable Energy Laboratory recently developed a small commodity inverter for PV that can accommodate energy storage and has four-quadrant operational capability that allows it to supply reactive power to the grid. There is also a demonstration at Los Angeles Air Force Base of electric vehicle-to-grid storage that can participate in the California ISO ancillary services market. Automated demand response (AutoDR) has been gaining national acceptance through the NIST Smart Grid standards development process and the results of these national efforts are expected to improve the performance and lower the system costs of implementing AutoDR. These innovations can apply to different types of distributed energy storage and are examples of the type of technology that needs to be deployed and refined for the future grid.

Energy storage is an area with a wide variety of beneficial uses and has accordingly received significant funding from different sources, such as the U.S. DOE. Research is underway in California to evaluate the benefits of adding distributed energy storage in a high PV penetration residential community in several configurations.

S2.4 Proposed Funding Initiative: Develop and Test Novel Technologies, Strategies, and Applications That Improve the Business Case for Customer-Side Dispatchable Distributed Resources and/or Expansion of Demand Response Capabilities.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X	X					X	X

Issue: Current customer-side dispatchable distributed resources are limited primarily to energy storage and CHP. Energy storage is typically provided by batteries which are large, expensive, and have limited capacity. In addition, the life expectancy of current batteries is short and replacement is costly. AutoDR has recently entered the market place with many new options that have not been integrated with other customer-sided energy resource systems. Past R&D has primarily focused on demonstration projects using existing technologies as opposed to developing new technologies or improving existing technologies. New technologies and strategies are needed to demonstrate that these new integrated, multiple energy source systems, can reduce the cost of customer-side applications.

Purpose: This initiative will develop and test new technologies and applications to reduce the cost and improve the performance of customer-side storage and expand DR capabilities. This initiative will conduct applied R&D in the following areas:

- Develop and assess the business case for the expansion of demand response capabilities and the automation of demand response services.
- Develop new technologies, such as printed batteries using ink technology, into working prototypes for pilot demonstrations: The U.S. DOE has provided significant funding over the last few years for basic research into advanced storage technologies. The Energy Commission will look for opportunities to address critical funding gaps to develop storage technologies into working prototypes, and demonstrate and evaluate the prototypes in pilot-scale applications.
- Research emerging storage technologies and novel applications identified in CPUC energy storage proceedings.
- Demonstrate emerging or proven storage technologies in novel applications: There may be opportunities to reduce the costs of customer-side storage by integrating storage technologies with other technologies such as AutoDR to create novel applications and strategies. For example, the Southeastern Pennsylvania Transportation Authority is using the same kind of braking technology found in hybrid vehicles – regenerative braking – to

convert energy from braking trains into electricity and store it in a battery system for future use or for sale back to the grid in times of high demand. This initiative will investigate and demonstrate innovative applications and strategies that improve the business case for customer-side storage.

- Demonstrate other types of dispatchable distributed resources in novel applications

Stakeholders: Ratepayers who wish to deploy energy storage, AutoDR service and other customer side energy systems, and utilities.

Background: Customer-side energy storage, AutoDR, and distributed energy resources continue to remain a high priority for achieving the state's policy goals for the electricity sector. Over the past few years, the Energy Commission has provided more than $6 million in cost-share funds for various energy storage projects in California funded through the American Recovery and Reinvestment Act of 2009 (ARRA), along with $9 million to support several non-ARRA energy storage projects. Also, in 2011, the Energy Commission provided funding to install and integrate an advanced lithium-ion battery system at the Santa Rita Jail in Alameda County. This storage system helps the jail reduce its electricity demand during summer peak to zero, allows the jail the potential to export energy, and provides congestion reduction and improved reliability to the local distribution grid. Additionally, the Energy Commission supported several ARRA funded field demonstrations of AutoDR to illustrate both the value and ease in which end customers can incorporate it into their operations.

Clean Generation

S3 Strategic Objective: Develop Innovative Technologies, Tools, and Strategies to Make Distributed Generation More Affordable.

Table 11: Ratepayer Benefits Summary for Strategic Objective 3

	Promote Greater Reliability	Lower Costs	Increased Safety	Societal Benefits	GHG emissions mitigation and adaptation	Lower emission vehicles/ transportation	Economic Development	Public Utilities Code Section 740.1	Public Utilities Code Section 8360
S3.1 Develop Next Generation Combined Heat and Power Technologies and Deployment Strategies.	x	x		x	x		x	x	x
S3.2 Develop Innovative Technologies, Techniques, and Deployment Strategies to Accelerate the Commercialization of Sustainable Bioenergy Systems.		x		x	x		x	x	x
S3.3 Develop Advanced Distributed Photovoltaic Systems to Reduce the Cost of Energy, Increase Interoperability, and Advance Plug-and-Play Capabilities.	x	x		x	x		x	x	x

Source: California Energy Commission

Distributed generation (DG) – small-scale power generation located close to electricity loads – can reduce or eliminate the need to build new utility-scale generators, transmission, and distribution infrastructure. It can also improve the efficiency of the electric system by avoiding transmission and distribution (T&D) losses that occur when electricity travels great distances over power lines to the distribution system. DG systems can also improve reliability by providing electricity and/or heat during grid outages. DG that delivers during peak demand periods can free up other generating capacity and ease transmission congestion.

The following initiatives aim to provide ratepayer benefits by reducing market barriers for DG systems, increasing the diversity of DG systems in the commercial market, and developing systems that provide direct benefits to electricity ratepayers. Furthermore, these initiatives will help advance the goals of Governor Brown's Clean Energy Jobs Plan, specifically the goals of adding 12,000 MW of distributed renewables by 2020 and 6,500 MW of CHP[54] capacity in the next 20 years to California's energy generation portfolio.

54 For the purposes of this objective, CHP includes combined cooling, heating, and power applications.

The Energy Commission will evaluate innovative ideas to increase performance over existing DG technologies in the lab and use results to guide the development of advanced bench-scale prototypes. Technologies and strategies that show promise will move to pilot-scale demonstrations to evaluate market potential. Further applied research will be conducted to evaluate where and how technologies should be deployed to maximize the benefits to California electricity ratepayers.

S3.1 Proposed Funding Initiative: Develop Next Generation Combined Heat and Power Technologies and Deployment Strategies.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X					X		X

Issue: In *Advanced Generation Roadmap Background Paper, 2009,* Navigant Consulting noted that "[t]echnology barriers have impeded full market deployment of industrial cogeneration systems. These barriers include system and component capital costs, emissions control, and fuel costs and flexibility. "[55] Upfront costs of installing CHP systems are a major barrier for many potential customers. Another major deterrent, particularly for reciprocating internal combustion engine systems, is the poor air emissions performance and inconsistent ability to cost-effectively achieve and sustain compliance with air emission standards. Advanced generation technologies such as microturbines and fuel cells emit fewer air pollutants but have other cost and operation-related barriers, some of which are discussed below.

CHP systems are also limited by the fact that they are sized for their thermal load, which sometimes results in excess electricity generation that does not provide additional value to the customer. The ability to match thermal load with potential end-use applications and customer-specific controls remains among the major technical issues. Other issues include the maintainability and durability of CHP systems, interconnection complexities (including telemetry requirements), and the flexibility to use alternative fuels and varying operational profiles. Compounding these issues are the perceived risk and uncertainty by potential customers about owning such a system, as well as a lack of technical expertise to conduct operation and maintenance.

55 Contreras, Jose Luis, David Walls, Erin Palermo, David Feliciano (Navigant Consulting, Inc.). *Advanced Generation Roadmap Background Paper, 2009*. California Energy Commission, PIER Program. CEC-500-2009-086. Page 64.

Navigant Consulting, Inc., noted the following challenges to widespread adoption of CHP technologies:[56]

- Fuel cells: unproven reliability, low stack life, and fuel reformer system design.
- Hybrid fuel cell-gas turbine technology: high front-end risk, cost of developing these systems, integration issues between fuel cell and turbine technologies, undemonstrated reliability.
- External combustion engines: lack of robust research and development, low efficiencies, unproven operational durability.
- Microturbines: unverified efficiency, emissions, and reliability claims; low electrical efficiency; and sensitivity to changes in ambient conditions.
- Small gas turbines: Require high-pressure gas or in-house gas compressor, poor efficiency at low loading, sensitive to changes in ambient conditions.
- Absorption chillers and inlet cooling systems, particularly fog intercooling, require additional research to identify ways to improve reliability, reduce corrosion and costs, and address other technical challenges.
- Recuperated gas turbine cycles: difficult to retrofit existing turbines.

Purpose: This initiative will solicit applied research and development to advance the technical, economic, and environmental performance of CHP systems – including combined cooling, heating, and power (CCHP) – that operate on renewable fuels, fossil fuels, or both. The goal of research in this area is to reduce technology costs and improve system components by addressing the challenges identified above through the following actions:

- Evaluate novel emission controls and strategies to meet air quality standards.
- Develop advanced technologies and strategies to improve prime mover performance and efficiency for emerging technologies. Applicants must demonstrate that the technologies they are developing will substantially improve performance and reliability and reduce costs over existing systems.
- Test and verify performance of fuel-flexible CHP/CCHP systems and innovative deployment strategies that expand California's CHP market potential.

To promote wide acceptance of CHP and realize its full benefits to ratepayers, this initiative will investigate technological improvements and cost-effective and environmentally sound

56 Contreras, Jose Luis, David Walls, Erin Palermo, David Feliciano (Navigant Consulting, Inc.). *Advanced Generation Roadmap Background Paper, 2009*. California Energy Commission, PIER Program. CEC-500-2009-086.

strategies for advanced CHP systems and prime movers. Funding will be prioritized on addressing the challenges identified above. Expected outcomes of research include:

- Increase the total energy conversion efficiency and reliability of the system.
- Reduce overall system costs through design improvements and development strategies.
- Develop advanced gas turbine cycles to promote hybrid systems and the use of renewable fuels.
- CHP-enabling strategies that will address a range of fuel flexibility and technical and economic improvement for heat recovery technologies.

Stakeholders: Ratepayers in industrial, commercial, institutional facilities and multifamily residences; local air quality districts; energy-smart community developments; and CHP industry groups.

Background: CHP is an important energy generation technology that caters to all three priority actions under California's loading order. It is a proven technology for improving energy efficiency and when viewed as such, qualifies as first in the loading order. CHP represents about 12 percent of the on-line power generation capacity in California. A majority of this CHP capacity is powered by fossil fuels, with limited capacity from renewable resources. The many benefits provided by CHP systems include reduced energy costs, more efficient fuel use, fewer environmental impacts, improved reliability and power quality, locations near load centers, and support of utility T&D systems.

ICF International released a report that evaluates several scenarios for CHP deployment in California over 20 years. The analysis indicated that a 10 percent capital cost reduction is needed by 2030 to achieve the penetration modeled in the high-case scenario. Previous research examined the development of lower-cost, high-performance CHP systems. Current research projects will address the technical and operational requirements for integrating multiple DG and CHP technologies and enabling technologies and for DG/CHP systems with multiple fuel capabilities. Some specific areas targeted by current research include emerging approaches for reducing criteria pollutant emissions, expanding applications for use of exhaust heat for process heating and cooling support, application of other exhaust components such as carbon dioxide from internal combustion engines, and strategies for cofueling of natural gas and biogas. Additional research will build on these emerging, emission-reduction and technology integration strategies, expanded potential applications, and other key project results to further reduce costs and enable further deployment of CHP and CCHP systems in California.

S3.2 Proposed Funding Initiative: Develop Innovative Technologies, Techniques, and Deployment Strategies to Accelerate the Commercialization of Sustainable Bioenergy Systems.[57]

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X	X				X		X

Issue: Biomass conversion technologies include thermochemical, biochemical, and physicochemical conversion processes. Physicochemical processes are mainly associated with the development of transportation biofuels. Thermochemical and biochemical processes are the dominant route for biomass electricity generation (or biopower) and are the focus of this discussion. Thermochemical conversion processes are expensive due to the low energy conversion efficiencies and the lack of full-scale deployment and require more research to drive down the costs and improve efficiency.

To ensure biopower is ecologically sustainable, California's biomass use policy limits harvest to feedstock derived as a secondary waste product or harvested from sustainable energy crops. Not all agricultural crop or forest residues should be harvested as some residues are needed to maintain soil fertility and tilth, or for erosion control. [58] Additional research is needed to develop uniform sustainability standards for biomass harvests.

Because biomass wastes are dispersed throughout the state, the cost to collect and transport the material significantly limits the feasibility of utility-scale bioenergy facilities. As diesel prices rise, the effective maximum radius for biomass collection sites decreases. Without innovative biomass handling systems that reduce biomass volume and improve energy content such as densification and torrefaction, or biomass collection approaches such as centralized biomass

57 Initiative supported by comments from California Biomass Energy Alliance; The Nature Conservancy; Natural Resources Defense Council; Union of Concerned Scientists; The Schatz Energy Research Center; Waste Management and Wheelabrator Technologies Inc.

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

collection and distribution stations,[59] most new biopower systems will only be economically sustainable at sizes of smaller than 10 MW. [60]

At small scales, internal combustion engines have been the most reliable generation technology. However, 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 emissions 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 off-the shelf low-emission generation technologies.

Purpose: Through this initiative, research will advance the development of state-of-the-art biomass conversion technologies, low-emission generation systems, and fuel handling and processing systems. It will also include studies on how to reduce environmental impacts from harvesting, ash disposal, and the supply of fuels. The goal of this initiative is to advance innovative approaches that show the greatest potential to reduce system costs and increase energy conversion efficiency. This initiative will conduct applied R&D in the following areas:

- Advanced Biomass-to-Energy Conversion Technologies: Biomass conversion technologies funded through this initiative include thermochemical and biochemical conversion technologies and approaches that can decrease production costs and/or otherwise increase the value of biogas. Innovative, lab-proven biomass conversion technologies and approaches should continue development into next generation prototypes to verify technical potential. Anaerobic digestion technologies will be examined for opportunities to reduce costs by increasing energy conversion efficiency and biogas production. Similarly, promising thermochemical technologies such as gasification, plasma arc gasification, and pyrolysis will continue to be developed and evaluated for reliability, conversion efficiency, cost-effectiveness, and environmental performance at the pilot scale.
- Improved Performance of Electricity Generators: To increase market acceptance of new conversion technologies, low-emission generation systems (including advanced pollution controls) will be developed and tested at pilot scale. To avoid duplication, biopower systems will be evaluated in coordination with other initiatives in this plan. Emissions profiles will be developed and made public on technology pairings with recommendations for future demonstration projects.

59 JDMT Consulting. http://www.energy.ca.gov/bioenergy_action_plan/documents/2010-12-14_workshop/comments/JDMT_Comments_TN-59368.pdf.

60 Larger facilities could be developed at sites that can support ecologically sustainable harvest and collection of biomass from locally derived feedstocks. The California Biomass Energy Alliance notes in their October 1, 2012 comments that the optimal size is defined by site location and biomass feedstock density.

- Sustainable Biomass Harvesting, Processing, and Handling Systems: Through this initiative, research will investigate technologies and approaches to reduce the cost and environmental impacts of collecting and transporting biomass feedstocks over greater distances, and increase the technical and economical availability of biomass feedstock throughout the state. Additional research topics include development and testing of innovative strategies to reduce the cost of fuel processing and handling systems.
- Advance research on sustainability standards for harvesting biomass in forestry and agricultural settings to ensure that future bioenergy development is environmentally sustainable.

Stakeholders: Ratepayers in rural and urban communities, industrial and commercial food processing facilities, dairy and agriculture facilities, and wastewater treatment facilities; California Department of Food and Agriculture; local air quality districts; ARB; California Department of Forestry and Fire Protection; biomass industry groups; California Department of Resources Recycling and Recovery; waste management industry.

Background: This initiative will address challenges identified in the *2009 Integrated Energy Policy Report*, the *2011 Bioenergy Action Plan*, [61] and the *Renewable Energy in California: Status and Issues* report. This initiative also supports the biomass activities specifically identified in the EPIC decision.

Unlike variable renewable energy resources, bioenergy technologies can provide reliable and renewable baseload generation, meaning that electricity can be generated during scheduled times and at predetermined power levels. Some bioenergy technologies can also increase or decrease output based on the demand for power.

Biomass waste streams produced by California's commercial, agricultural, and industrial practices can be used as a fuel for combustion, or as a feedstock to produce biogas that can then be used to generate electricity. A number of emerging technologies and processes can be used to convert biomass into biogas (or producer gas), and each has its advantages and disadvantages. DG systems can then use the biogas to generate electricity. Bioenergy has many benefits compared to other forms of energy generation, including displacing fossil fuel power plants with a reliable renewable resource; generating distributed energy near demand; reducing GHG emissions, providing jobs in rural communities; providing agriculture, industry, and forestry

61 California has adopted numerous policies to promote bioenergy, but significant barriers to its development remain. The *2011 Bioenergy Action Plan* identifies those barriers and recommends actions to address them, so that the state can meet its clean energy, waste reduction, and climate protection goals. The *2012 Bioenergy Action Plan* reflects an update to the actions in the 2011 Plan, but does not update the challenges. For more information on California's Bioenergy Action Plan, please go to: http://www.energy.ca.gov/bioenergy_action_plan.

with an effective disposal option for biomass residues; and reducing wildfire severity and the use of landfills.

Biomass harvesting, handling, and processing systems include strategies and approaches to reduce the overall delivered cost of biomass to end users. This can include, but is not limited to, innovative approaches to collecting and harvesting biomass, technologies and strategies to increase the biomass energy density, and innovative collection systems such as strategically placed distributed biomass fuel yards.

Through the Alternative and Renewable Fuel and Vehicle Technology Program and under Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007), the Energy Commission is required to "establish sustainability goals to ensure that alternative and renewable fuel and vehicle projects . . . will not adversely impact natural resources, especially state and federal lands."[62]

Sustainability research should build on and complement the research that has been undertaken by various agency and conservancy organizations throughout California.

The U.S. DOE is funding thermochemical research projects to develop conversion and upgrading technologies, focusing on the low temperature pyrolysis to bio-oil pathway. Current projects focus on enabling biorefineries to convert woody biomass efficiently into biofuels at demonstration and commercial scales.[63] The conversion technology research funded through this effort will apply to biopower systems.

Recent research efforts in California include preliminary evaluations of forest biomass conversion and the tradeoffs between power generation and biofuels production; economic and environmental analysis of dairy digester technologies; air quality implications of various conversion pathways and DG technologies; and low-emission technologies to enable CHP production from biogas and landfill gas. EPIC investments will advance this knowledge base and build on recent project results, with particular focus on strategies to enable sustainable forest biomass collection and conversion, increase energy generation from agricultural waste streams, and develop low-cost emission control and advanced generation technologies to enable increased use of biomass in small-scale applications.

62 Baroody, Leslie, Charles Smith, Michael A. Smith, Charles Mizutani. 2010. 2*010-2011 Investment Plan for the Alternative and Renewable Fuel and Vehicle Technology Program Commission Report.* California Energy Commission, Fuels and Transportation Division. Publication Number: CEC-600-2010-001-CMF. Page 101.

63 http://www1.eere.energy.gov/biomass/thermochemical_conversion.html.

S3.3 Proposed Funding Initiative: Develop Advanced Distributed Photovoltaic Systems to Reduce the Cost of Energy, Increase Interoperability, and Advance Plug-and-Play Capabilities.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X					X		X

Issue: Current incentives for PV technologies are unsustainable over the long term, and further cost reductions are necessary for PV to become cost-competitive with conventional generation in California. While the cost of PV cells has decreased in recent years, the cost of other system components, such as inverters and racking systems, has not fallen quite as fast. Integrated, low-cost, off-the-shelf systems need to be developed and brought to market to increase plug-and-play capabilities and interoperability of distributed PV systems with other DER.

The focus of the CPUC's California Solar Initiative (CSI) RD&D plan includes a narrow set of investment areas including production technologies, grid integration, and business, development, and deployment.[64] This leaves a research gap on advanced system components and other strategies to further reduce nonhardware costs of PV energy generation.

As the penetration of distributed PV continues to increase, so does its impact on distribution feeders in California, and a number of integration issues arise for utilities and grid operators. Several European countries require all inverter-based PV to autonomously support volt-VAR and frequency management functions.[65] Currently, IEEE 1547 and California Rule 21[66] do not allow for the interconnection of these advanced inverter technologies. Further research is required to verify the reliable performance of PV systems with advanced inverter functionality and advise standards for the development of such systems.

Purpose: This initiative will develop next generation, low-cost distributed PV system hardware components and power electronics designed to work in concert with other DERs and to enable communications between inverters and customer premise networks (CPNs), as discussed in

64 CPUC. 2007. *The Adopted California Solar Initiative Research, Development, and Demonstration Plan*. http://www.calsolarresearch.org/images/stories/documents/csi_rdd_adopted_plan_73189.pdf.

65 http://www.energy.ca.gov/2011_energypolicy/documents/2011-06-22_workshop/presentations/06%20Frances%20Cleveland%20-Xanthus%206-20-Advanced%20Inverter-based%20DER%20Functions%20-%20CEC%20Panel%20v2.pdf.

66 http://www.cpuc.ca.gov/PUC/energy/Procurement/LTPP/rule21.htm.

initiative S6.5*: Develop Smart Grid Communication Systems That Interface With Customer Premise Networks and Distributed Energy Resources*. This initiative will also support the development and evaluation of comprehensive approaches to reducing the cost of energy for PV, and investigating strategies and business models to ensure that commercial PV systems are readily available and provide the functionality needed for customers and the utility grid. The Energy Commission will evaluate PV systems that are easily and quickly deployable as well as technology advances and strategies to increase the value of distributed PV systems in energy-smart communities. This initiative will conduct applied R&D to improve the economic performance of distributed PV, such as:

- Advanced concentrating PV technologies and designs: To reduce costs and increase PV system performance, this initiative will develop and evaluate innovative concentrating PV systems, including concentrator designs, low-cost and high accuracy advanced tracker systems, system integrated inverters with advanced functionality, and strategies to use heat generated as a by-product of concentrating sunlight to increase system efficiencies. Concentrating PV systems use optical concentrators to focus incident radiation onto a small PV cell, generating heat. Typically, this heat is dissipated into the surrounding environment as waste, but there are several technologies that look to use this waste heat in useful CHP applications, thereby increasing the overall system efficiency.
- Low-cost building-integrated PV materials: This initiative will further reduce costs by developing building-integrated PV and hybrid solar systems that are fully integrated into building designs, including roofing surfaces, window materials, and/or other building elements. These systems should work in concert with other energy components within the building to advance California's ZNE buildings goals. Applied research activities will also inform standards for the integration of PV systems into new residential and commercial buildings.
- Advanced PV inverter functionality and interoperability: This initiative will develop and evaluate smart PV inverter technologies that can autonomously monitor local grid conditions and respond accordingly. Inverter functionalities will include volt-VAR control, dynamic grid support during low-voltage ride through, remote communications, and power curtailment. Advanced inverter technologies and smart grid components will be developed and integrated into packaged PV systems to increase interoperability with other co-located DER including energy storage, electric vehicle chargers, and other smart grid resources enabling the development of energy-smart communities and local microgrids. This initiative will support research to develop the abilities of PV systems to communicate with Local Area Networks to securely provide real-time system performance information to customers and utilities.
- Strategies to reduce nonhardware costs of PV: This initiative will develop and evaluate strategies to reduce the nonhardware costs for distributed PV across the entire value chain – including manufacturing, distribution, installation, operations, and end-of-life system

considerations. The Energy Commission will identify any untapped opportunities for nonhardware cost reduction and investigate strategies to strengthen the business case for distributed PV systems in California.

- Hardware technologies for self-identification of DER equipment such as communication chips embedded in the DER systems, to automatically identify distributed energy resources as they interconnect to the utility's grid. This initiative will develop and evaluate embedded hardware to limit the safety risks associated with otherwise undetected DER installations. The utilities have related but separate pilot demonstrations of "auto registration" of DER equipment using their smart meter data to see changes in their energy use profile from the installation of DER equipment. This initiative will research embedded hardware that will provide direct communication of device information to increase the visibility of the individual DER equipment.

Stakeholders: Ratepayers in residential, commercial and industrial facilities; California ISO; IOUs; CPUC; energy-smart community developments; distributed PV installers; solar industry groups.

Background: The CPUC administers the CSI RD&D program. Through this program, $50 million of the CSI funds are directed to research, development, demonstration, and deployment projects. The RD&D program runs through 2016, and is funded by the electric ratepayers of California's three largest IOUs, PG&E, Southern California Edison Company (SCE), and SDG&E as described in Decision 06-12-033.[67]

Although solar is one of California's most promising renewable resources, it is not yet cost-competitive with conventional electricity generation. Particularly over the long term, as PV subsidies expire, funding research now can continue to reduce costs (both technology and "soft" costs) and continue advancing California's PV industry. CSI RD&D will invest up to $50 million by 2016 pursuant to Public Utilities Code Section 2851.[68] Through this proposed initiative, the Energy Commission will seek opportunities to complement the advances made by the CSI RD&D program and avoid duplicative efforts.

A significant research effort is underway at the federal level with the U.S. DOE's SunShot Initiative, which aims to reduce the cost of solar energy 75 percent by 2020. As part of this effort, the U.S. DOE launched the Rooftop Solar Challenge to reduce nonhardware PV costs and

67 CPUC. 2007. *The Adopted California Solar Initiative Research, Development, and Demonstration Plan*. http://www.calsolarresearch.org/images/stories/documents/csi_rdd_adopted_plan_73189.pdf.

68 Public Utilities Code Section 2851 (c)(1) establishes a CSI R&D funding cap of $50 million. It provides in pertinent part: "In implementing the California Solar Initiative, the commission [CPUC] shall not allocate more than fifty million dollars ($50,000,000) to research, development, and demonstration that explores solar technologies and other distributed generation technologies that employ or could employ solar energy for generation or storage of electricity or to offset natural gas usage…"

improve market conditions for PV projects. This nationwide effort engages diverse teams of local and state governments along with utilities, installers, nongovernmental organizations, and others to make solar energy more accessible and affordable.[69] The SunShot initiative presents a significant opportunity for California to leverage U.S. DOE funding while maintaining the state's track record of innovation and early adoption.

In recent years, several research projects have focused on ways to advance distributed PV technologies and California's PV industry as a whole. For example, SolarTech has looked at comprehensive ways to reduce the cost of solar energy through permitting, installation, and other "soft cost" reductions. Other projects have sought to reduce costs with innovative technology designs and low-cost installation strategies. While promising advances were made in these projects, further cost reduction opportunities exist that are essential to the long-term viability of distributed PV in California.

The proposed IEEE 1547.8 update should allow higher penetrations of inverter-based DER, including PV, but it is still under development. The purpose of the update is to provide more flexibility in determining the design and processes used in expanding implementation strategies for interconnecting distributed resources with electric power systems.[70] Developing and deploying advanced inverter technologies will improve power system efficiency, delay the need for distribution upgrades, and help avoid grid outages. Inverter manufacturers are already including advanced functions for the European market, and lessons learned could be leveraged to develop optimized upgrades for California's environment. Results of applied research in this area could be used to advise any updates to California's Rule 21.

69 http://www.eere.energy.gov/solarchallenge/.

70 http://www.4thintegrationconference.com/downloads/Distribution%20Grid%20Codes%20Tutorial_PPL%20Electric_Bassett.pdf.

S4 Strategic Objective: Develop Emerging Utility-Scale Renewable Energy Generation Technologies and Strategies to Improve Power Plant Performance, Reduce Costs, and Expand the Resource Base.

Table 12: Ratepayer Benefits Summary for Strategic Objective 4

	Promote Greater Reliability	Lower Costs	Increased Safety	Societal Benefits	GHG emissions mitigation and adaptation	Lower emission vehicles/ transportation	Economic Development	Public Utilities Code Section 740.1	Public Utilities Code Section 8360
S4.1 Develop Advanced Utility-Scale Thermal Energy Storage Technologies to Improve Performance of Concentrating Solar Power.	X	X		X	X			X	X
S4.2 Develop Innovative Tools and Strategies to Increase Utility-Scale Renewable Energy Power Plant Performance and Reliability.	X	X		X	X			X	X
S4.3 Develop Advanced Technologies and Strategies to Improve the Cost-Effectiveness of Geothermal Energy Production.	X	X		X	X			X	X
S4.4 Investigate the Economic, Environmental, and Technical Barriers to Offshore Wind in California.	X	X		X	X			X	X
S4.5 Investigate the Economic, Environmental, and Technical Barriers to Wave Energy Conversion Technologies in California.	X	X		X	X			X	X

In response to the adoption of the 33 percent RPS and Governor Brown's Clean Energy Jobs Plan goal of deploying 8,000 MW of large-scale renewable energy systems by 2020, California has aggressively pursued greater reliance on renewable energy sources. As a result, the state leads the nation in electricity generation from nonhydroelectric renewable energy sources, including solar, wind, geothermal, and biopower generation. While gas-fired generation and nuclear power continue to play significant roles in the state's electricity system, the focus is on protecting the environment and creating jobs through developing and integrating renewable energy sources. R&D initiatives identified in this objective will focus on utility-scale renewable energy sources, specifically solar PV and concentrating solar thermal, geothermal energy, and emerging offshore renewable technology opportunities.

The Energy Commission will fund research to improve the cost and performance of existing utility-scale clean energy generation, which is defined as a standalone generation facility that is directly connected to the grid and is 20 MW or greater in capacity. Research on clean energy

generation will also be targeted at filling knowledge gaps and technology needs to deploy and integrate emerging utility-scale renewable energy technologies in a stable, secure, and environmentally friendly way. Funding initiatives focus on system engineering in addition to developing data, technologies, and tools for planning and operating large renewable energy power plants that work with state, regional, and local transmission resources. Incremental improvements in technology, as well as innovative breakthroughs, will be sought through applied research in bench- and pilot-scale developments.

Additionally, developing utility-scale clean energy technologies and precommercial applications need investment. Two such emerging energy technologies that may be able to contribute to California's RPS goals are offshore wind and marine renewable energy. California has considerable electricity generation potential located in offshore resource areas but comprehensive research is needed to analyze the technical economic barriers facing the development of these resources.

S4.1 Proposed Funding Initiative: Develop Advanced Utility-Scale Thermal Energy Storage Technologies to Improve Performance of Concentrating Solar Power.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X					X		X

Issue: Integrating thermal energy storage (TES), a means of storing thermal energy for later use, with concentrating solar power (CSP) plants allows energy to be generated during off-peak periods and used when needed, reducing system variability and evening peak demand. The National Renewable Energy Laboratory [71] estimates that the use of TES may allow CSP plants to achieve annual capacity factors of up to 70 percent or more, a significant increase over plants without thermal storage. CSP plants integrated with TES can provide not only firm capacity, but also high−value ancillary services such as spinning reserves.

There are several drawbacks to the use of TES systems, including additional costs and the need to oversize the solar field. Further research is needed to reduce the cost of TES and improve the properties of heat transfer fluids to maximize CSP plant performance.

Purpose: This initiative will support research to improve TES for CSP applications. This initiative will also seek research on storage media with improved thermal and physical

71 NREL website: Hhttp://www.nrel.gov/csp/troughnet/thermal_energy_storage.html. Accessed August 23H, 2012.

properties and advanced heat transfer fluids for CSP plants, such as organic salts and molten metals. Research on heat transfer

fluids for direct use in solar plant operation may be coupled with research under this initiative.

Stakeholders: Utilities, ratepayers, California ISO, independent energy developers, the U.S. DOE and operators, energy academia, and renewable energy industry groups.

Background: A variety of different heat transfer fluids, which are used to transport heat to the power block, have also been used to assess energy storage potential in CSP plant operations.TES has been demonstrated with a number of alternative heat transfer materials, such as petroleum-based products and molten salt. TES using molten salt storage seems to hold the greatest promise of economic commercialization. Molten salt systems, usually a mixture of 60 percent sodium nitrate and 40 percent potassium nitrate, allow the solar field to operate at higher temperatures relative to other fluids or storage media, returning as much as 93 percent of the energy sent into storage. Storage capacities from 3-12 equivalent full load hours have so far been evaluated.

The U.S. DOE has funded research on thermal energy storage through the SunShot Initiative. In 2008, the U.S. DOE SunShot Initiative funded 15 projects looking at advanced heat transfer fluids and novel thermal storage concepts for concentrating solar power generation for around $67.6 million. TES topics addressed by these projects included the use of molten salt carbon nanotubes, the use of liquid CO_2 as the heat transfer fluid, and using solid ceramics for the energy storage vessels. In August 2012, the U.S. DOE announced new investments totaling $10 million for two university-led projects to advance innovative CSP system technologies. One of these awards was for a collaborative research team including University of California, Los Angeles, and University of California, Berkeley, to investigate liquid metals as potential heat transfer fluids with the ability to withstand higher temperatures.

KEMA is researching thermodynamic modeling of different solar generation-thermal storage configurations to identify optimal approaches for dispatch applications. In 2011, KEMA began to evaluate the economic potential of CSP plants integrated with TES and develop models to examine the relative performance of a variety of TES technologies for CSP plant applications. Future Energy Commission work should expand this effort to include emerging TES technologies and configurations.

S4.2 Proposed Funding Initiative: Develop Innovative Tools and Strategies to Increase Utility-Scale Renewable Energy Power Plant Performance and Reliability.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X					X		X

Issue: Both solar PV and CSP technologies present challenges to operation of the power system due to the variability and the relative uncertainty of their generation output. Specific technical concerns related to intermittency involve grid stability, voltage regulation, and power quality (voltage rises, sags, flickers, and frequency fluctuations).

As there is a relatively small amount of installed solar capacity, the characteristics of solar technology (PV and CSP) power output are not well established. Initial experience with PV indicates that output can vary more rapidly than wind unless aggregated over a large area. There is also a need for modeling to smooth regional variations in generation, reducing the need for highly accurate forecasts. To facilitate utility-scale solar generation integration into the grid, there is a need to improve forecasts that inform grid operators of upcoming variability and to smooth regional generation variability.

Purpose: This initiative will support research solutions to improve intermittent renewable energy integration into the state's electrical grid through developing improved forecasting and modeling tools. To enable the integration of increasing amounts of utility-scale solar generation into the grid, research under this initiative will develop and evaluate improved forecasting techniques and tools to inform grid operators of expected power plant performance on minutes-ahead, hours-ahead, and days-ahead time scales.

Expanding on past efforts, the suite of existing solar forecasting tools and models should be integrated and developed into a best-mix forecast tool for grid operators to incorporate into planning processes and dynamic operation of the grid. This initiative will also develop advanced modeling techniques and real-time resource assessments to smooth regional variation in generation, reducing the need for increasingly accurate forecasts.

Stakeholders: Utilities, ratepayers, California ISO, independent energy developers, the U.S. DOE and operators, energy academia, and renewable energy industry groups.

Background: Research has been conducted to develop solar energy forecasting and monitoring tools for a spectrum of time scales, from minutes ahead to hours ahead to days ahead. There are several distinct forecasting techniques that each provides more accurate forecasts within certain timeframes, including total sky imagers for minutes ahead, satellite-based cloud vector analysis

for hours ahead, and numerical weather prediction models for days ahead. Recent research is evaluating the feasibility of integrating these three tools into one seamless forecasting tool. Future research activities should build from these efforts and support the pilot demonstration of an integrated forecasting tool in the California ISO planning, such as the one described below. The California ISO[72] calls for improved day–ahead forecasting through numerical weather models with a focus on marine layer clouds. This can be achieved through developing advanced algorithms to ingest satellite and ground measurements to model for cloud cover as well as developing tools to select forecast models based on meteorological conditions.

The University of California, San Diego, has performed extensive R&D in this area, particularly using shorter-time frame forecasting techniques and predicting the onset of localized weather events such as marine layers. The National Oceanic and Atmospheric Administration (NOAA) recently completed a two-year project with the U.S. DOE to improve forecasts of turbine-level (or boundary layer) winds using high-resolution numerical models. Other private entities, such as Clean Power Research and AWS Truepower, have performed Energy Commission-sponsored forecasting research in collaboration with the California ISO. Further research is needed to integrate each approach into a best-mix tool that provides accurate forecasts of solar plant output across each time scale.

The U.S. DOE SunShot Initiative and CSI RD&D program have both supported research into forecasting for solar generation. EPIC investments will be coordinated with these and other programs to avoid duplication and leverage project results from these programs.

S4.3 Proposed Funding Initiative: Develop Advanced Technologies and Strategies to Improve the Cost-Effectiveness of Geothermal Energy Production.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations/ Market Design	Generation	Transmission/ Distribution	Demand – side Management
X					X		X

Issue: Challenges to increased geothermal development stem from the fact that exploration and resource characterization activities are expensive and time consuming, and therefore, necessitate long lead times for project development. Permitting and environmental considerations, such as emission of toxic air pollutants and possible impacts to water resources, are also major barriers. Exploration, drilling, and resource development can account for roughly

72 California ISO Research Topic Area Comment on EPIC Investment Plan TN-66713. Submitted August 16, 2012.

half of the capital costs associated with construction and operation of a geothermal power plant. Consequently, improvements in exploration and drilling technologies and resource assessment capabilities may hold the greatest potential for geothermal power plant cost reductions.

Purpose: This initiative will research improvements to geothermal resource characterization and development tools and analytical techniques to help reduce risks associated with development of a variety of geothermal systems, including hydrothermal, enhanced, and geopressurized systems. An area for advancement includes developing exploration and characterization tools to locate and characterize low- and moderate-temperature hydrothermal systems before drilling, thereby reducing well field costs. Research activities will also address downhole, high-temperature tools and electronics to improve geothermal subsurface operations, as well as improved drilling mechanisms, such as steering technologies. Ensuring reservoir productivity is also a priority, so the initiative will also research refinements to the techniques and modeling tools needed to quantify production and injection impacts on geothermal reservoirs. Alternative working fluids for hot, dry rock resources, such as CO_2, will also be addressed. Lastly, the initiative will address research to improve existing geothermal plant efficiency, reduce corrosion and scaling, recover useable metals from spent geothermal brine, and improve cooling technology.

Stakeholders: Utilities, ratepayers, geothermal energy developers and operators, resource exploration and characterization companies, the U.S. DOE, and geothermal industry groups.

Background: The U.S. DOE's Geothermal Technologies Program conducts in-house research on exploration, characterization, and development tools for enhanced geothermal systems, including high-temperature tools and sensors, advanced drilling systems for enhanced geothermal systems, resource characterization and validation studies, and research on geothermal water use. Forty-six research projects have been funded in California through different U.S. DOE solicitations. EPIC geothermal research can use and build upon these federally supported research efforts to help improve and support California-specific geothermal research.

The Energy Commission administers the Geothermal Grant and Loan Program, which is funded by the state's Geothermal Resources Development Account. The objective of the Geothermal Grant and Loan Program is to promote planning and development of new or existing geothermal resources and technologies in California; however, certain research activities are not eligible for funding under this program. EPIC funding will be used to complement California's existing geothermal research projects and leverage geothermal development funding opportunities from the U.S. DOE.

S4.4 Proposed Funding Initiative: Investigate the Economic, Environmental, and Technical Barriers to Offshore Wind in California.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X				X	X	X	

Issue: There are number of remaining barriers that need to be investigated before offshore wind can be developed in California. The average water depth on the West Coast increases far more rapidly than most other coastal regions in the United States, which means that the highest quality wind resources are located in deep water. While shallow water offshore wind technologies are being developed rapidly in Europe, additional research is needed to address concerns of offshore wind in California's unique marine environment.

Environmental concerns are potentially a major barrier to offshore wind energy development. For example, good potential offshore wind resources may be in the migration path of sea mammals and birds, increasing the risk of collision with turbine blades. Noise and vibration from construction and operation of the wind turbine may also disrupt marine species' behavior.

Some of the technology advancements needed for deepwater offshore wind include larger capacity turbines and innovative integrated turbine configurations (rotor, drivetrain, tower, controls) to counterbalance their additional capital cost. To increase wind turbine capacity, weight needs to be reduced by developing innovative blade designs and lighter weight composite materials. Construction and operation costs can be reduced by simplifying installation and reducing maintenance requirements. Further analysis is needed to evaluate economic and technical feasibility and any additional technology advancements that will be needed.

The U.S. Department of Defense urges that offshore wind should be located and developed in a manner that does not put future constraints on military testing and training. Interagency coordination with U.S. DOD and other stakeholder groups will be an important aspect of this initiative. Oregon has addressed this by developing a comprehensive marine spatial plan that incorporates the needs of marine renewables.

Purpose: This initiative will evaluate the costs, environmental concerns, and technology needs for offshore wind energy systems in California, including the underwater transmission infrastructure necessary to connect with California's electricity grid. Research activities will identify the specific benefits, disadvantages, and trade-offs of offshore wind technologies, which could lead to future demonstrations in California.

Potential applied research topics include, but are not limited to:

- Evaluating societal impacts under various deployment scenarios
- Evaluating deep-water foundations and innovative component designs to baseline technology platforms, evaluating cost-effectiveness, and identifying lowest cost options.
- Identification of priority locations and siting constraints for offshore wind installations.
- Developing modeling tools to evaluate installation configurations.
- Evaluating grid integration impacts of offshore wind energy.

Environmental research on offshore wind development is also discussed in S5.3: *Develop Analytical Tools and Technologies to Reduce Energy Stresses on Aquatic Resources and Improve Water-Energy Management.*

Stakeholders: Utilities, ratepayers, coastal communities, U.S. Bureau of Ocean Management, Regulation and Enforcement Ocean Protection Council, offshore wind developers, U.S. DOD, and the U.S. DOE.

Background: The U.S. DOE's National Renewable Energy Laboratory has been conducting in-house research on offshore wind for nearly a decade. The program is focused on improved resource characterization, grid integration, and standards development. The U.S. DOE also funded $20 million of research in 2011 to explore technology development and removing market barriers. More recently, funding opportunities were announced to demonstrate emerging offshore wind energy systems in United States waters, including the U.S. DOE *Offshore Wind: Advanced Technology Demonstration Projects*.[73] This grant opportunity provides funding for two topics: pilot-scale deployment and assessment of commercial viability. Multiple proposals were submitted for demonstration projects in California, but awards have yet to be announced. While no offshore wind projects have been demonstrated in California, interest in developing these resources has recently increased.

73 http://www1.eere.energy.gov/wind/financial_opps_detail.html?sol_id=473.

S4.5 Proposed Funding Initiative: Investigate the Economic, Environmental, and Technical Barriers to Wave Energy Conversion Technologies in California.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X				X	X	X	

Issue: Currently, the estimated costs to purchase, install, maintain, and operate wave energy converter systems in California and the underwater transmission infrastructure necessary to connect them to the grid far exceed those of fossil fuel generation and other renewable resources. Compounding the cost issue are concerns about the effects that marine renewable energy technologies may have on marine animals and benthic (sea bed) ecosystems.

The potential environmental impacts of marine renewable energy include dangers to marine life from working fluid leakage, electromagnetic fields, sounds and vibrations produced during electricity generation, and the impacts of erosion and sediment flows on natural coastal processes. Potential interference with U.S. DOD training and testing activities, commercial and recreational fishing activities and marine sanctuaries are all possible siting constraints for wave energy development. These environmental compliance and siting issues will require significant attention and interagency coordination before a demonstration project is possible in California.

Purpose: This initiative will investigate the environmental, economic, and technical issues with marine renewable energy technologies, including underwater transmission and substations. Technologies will be evaluated for their cost, reliability, and environmental performance in California's waters. Integration issues surrounding deployment of these marine energy technologies will be addressed along with the research to scope the potential environmental barriers to wave energy deployment.

Extreme events (typically 50- or 100-year return events) are important design considerations when evaluating the structural loads on marine energy installations. Such loads are induced by winds, currents, waves, tsunamis, and seismic activities. These events need to be properly characterized using existing data to form the design basis for marine energy installation in California.

Stakeholders: IOUs, ratepayers, coastal communities, U.S. Bureau of Ocean Management, Regulation and Enforcement Ocean Protection Council, offshore wind developers, U.S. DOD, and the U.S. DOE.

Background: A large variety of wave energy converter technologies have been tested and demonstrated in other states and in Europe with varying degrees of success. Attenuators, point

absorbers (power buoys), oscillating water columns, and multipoint absorbers are just a few of the wave energy converter technology types that have emerged over the last several years.

Previously, PG&E had proposed several wave energy demonstration projects off the Northern and Central California coasts with its WaveConnect program. These demonstration projects would have included four different wave energy technologies and generated 5 MW of grid connected electricity. PG&E opted to discontinue the project due to development and operation costs beyond what they were willing to spend on unproven technologies.

The U.S. DOE Wind and Water Power Program supports R&D on a wide range of advanced marine renewable energy technologies, with the objective of better understanding their potential for energy generation, and identifying and addressing the technical and nontechnical barriers to their application and deployment, through programs such as the Marine and Hydrokinetic Technology Readiness Advancement initiative.[74] Specific activities addressed by the U.S. DOE in recent years have included component and device development, device testing, national marine renewable energy testing centers, array design, development, modeling and testing, and technology evaluation. This broad range of activities has resulted in a number of R&D funding opportunities that have not yet been fully leveraged by California's R&D funding agencies, including the Energy Commission.

Most recently, Ocean Power Technologies, a wave energy device developer, announced that it has received approval from the U.S. Federal Energy Regulatory Commission (FERC) for a planned 1.5 MW wave energy installation off the coast of Oregon. This is the first FERC license for a commercial wave power facility issued in the United States. The license provides a regulatory approval for the deployment of up to 10 wave energy converter devices.

74 https://www.fedconnect.net/FedConnect/?doc=DE-FOA-0000293&agency=DOE.

S5 Strategic Objective: Reduce the Environmental and Public Health Impacts of Electricity Generation and Make the Electricity System Less Vulnerable to Climate Impacts.

Table 13: Ratepayer Benefits Summary for Strategic Objective 5

	Promote Greater Reliability	Lower Costs	Increased Safety	Societal Benefits	GHG emissions mitigation and adaptation	Lower emission vehicles/transportation	Economic Development	Public Utilities Code Section 740.1	Public Utilities Code Section 8360
S5.1 Conduct Air Quality Research to Address Environmental and Public Health Effects of Conventional and Renewable Energy and to Facilitate Renewable Energy Deployment.			x	x					
S5.2 Research on Sensitive Species and Habitats to Inform Renewable Energy Planning and Deployment.		x	x	x			x		
S5.3 Develop Analytical Tools and Technologies to Reduce Energy Stresses on Aquatic Resources and Improve Water-Energy Management.	x		x	x					
S5.4 Develop Analytical Tools and Technologies to Plan for and Minimize the Impacts of Climate Change on the Electricity System.	x		x	x					

Source: California Energy Commission.

As California moves toward achieving a 33 percent RPS and the GHG reduction goals of the Global Warming Solutions Act, the state must balance the need for renewable energy development with appropriate levels of environmental protection. Lack of suitable information and tools has emerged as a major source of uncertainty and delay in the permitting and deployment of renewable energy projects. Development delay can increase the cost of achieving the RPS, and these costs are generally passed to the ratepayer. This is readily apparent in the Southern California desert where traditional approaches to avoiding and mitigating environmental impacts of proposed solar projects have proved inadequate. Furthermore, the state's existing electricity system continues to contribute to the overall degradation of land, air, and water resources while adversely affecting public health.

The environmental costs and benefits of renewable energy policies, conventional and emerging energy technologies, and system performance in achieving the state's RPS and GHG emission goals must be understood to give decision makers the tools and information they need to

balance environmental protection and energy development. This translates to achievement of goals at a lower cost to the ratepayer, both in terms on dollar cost and environmental impact.

The initiatives under this strategic objective address research on air quality, habitat protection, and water resources associated with the existing electricity generation systems, including fossil fuel and renewable energy sources. Most public health research will be addressed under the air quality funding initiative. Research under this initiative will also assess environmental issues associated with emerging renewable energy technologies, the interaction of climate change with the electricity system, and the electricity system's future evolution.

S5.1 Strategic Initiative: Conduct Air Quality Research to Address Environmental and Public Health Effects of Conventional and Renewable Energy and to Facilitate Renewable Energy Deployment.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X					X		

Issue: The emphasis on adding renewable generation to the California energy mix has not replaced the requirement for new natural gas power plants. There is a need to understand how the new electricity system will function and affect air quality. Also, there is a need to identify new sources of air pollution offset credits because credit scarcity is affecting the ability to site new plants where they are needed. This in turn may impact customer reliability. It will also be critical to understand the potential air quality impacts of new generation technologies and fuels – as well as control technologies and mitigation strategies – as the state strives to meet its renewable energy and GHG emission reduction goals. This challenge is especially true for biopower, which faces major siting and permitting challenges due its potential air quality impacts. At the same time, the electrification of some energy services (for example, transportation and water heating) can be a tool to improve air quality conditions in California. Emissions inventories and assessments of the spatial distribution of emissions from biopower generation are needed to evaluate potential air quality benefits/impacts.

The *2012 Bioenergy Action Plan* identifies the need for additional R&D to ensure that energy production is environmentally and economically sustainable. Because biopower produces air pollution emissions of ozone precursors and particulate matter in each phase of development – from feedstock collection, transportation, and processing to generation – compliance with air quality standards may be a major factor in bioenergy siting. Emission factors for certain technologies and feedstocks are incomplete and need further research. Bioenergy gasification

presents another area in need of research because emissions from bioenergy gasification and combustion vary significantly based on the feedstock source and the gasification technology.

Purpose: This initiative will evaluate air quality impacts of the current IOU electricity system, which is predominantly natural gas-fired generation, including how to address the shortage of pollutant offsets for new generation. Air quality research will also focus on new generation technologies and fuels for electricity generation. This research, which will be closely coordinated with the ARB and air quality districts, will inform improved emissions estimates for generation technologies and fuels and improved mitigation strategies.

Public health research will focus on short-term dispersion modeling to inform understanding of pollution exposure in disadvantaged communities located near electricity generating facilities. Air quality research will also investigate the formation, composition, measurement, and population exposure to particulate matter, particularly ultrafine particulate matter (less than 100 nanometers in size).

Stakeholders: Ratepayers, utilities, research institutions, non government organizations (NGOs), ARB, U.S. Environmental Protection Agency (U.S. EPA), Air Quality Management Districts.

Background: Since 1971, the ARB has sponsored more than 245 research projects on public health effects of air quality and sources, controls, and inventories of air pollutants. Recent ARB bioenergy research has focused on developing transportation fuels. In recent years, research funding has totaled slightly more than $5 million in each of the annual research plans. Research identified in the plans has been heavily focused on transportation-related issues. For example, ARB's Fiscal Year 2012-2013 Research Plan[75] identifies about $5.65 million in air quality research entirely focused on the transportation sector.

Coordinating with the ARB, local air districts, and stakeholders, the Energy Commission has focused on developing new test methods, instruments, and tools capable of measuring emissions from small and large generation sources and predicting both local and regional air quality impacts. It is supporting research on the air quality issues related to biogas from anaerobic digestion of food waste, the air quality impacts of implementing the RPS, and economically and environmentally viable strategies for conversion of bioresources to power. Other organizations such as the U.S. EPA and the New York State Energy Research and Development Authority have conducted similar research on ozone and particulate matter health effects, but additional California utility-specific research is needed.

75 California Air Resources Board, Fiscal Year 2012 – 2013 research Plan. June 2012. http://www.arb.ca.gov/research/apr/plan/fy12-13/2012-13_arb_HannualH_research_plan.pdf.

S5.2 Proposed Funding Initiative: Research on Sensitive Species and Habitats to Inform Renewable Energy Planning and Deployment.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X					X		

Issue: Increasing renewable energy production can yield numerous environmental and societal benefits by reducing GHG emissions and dependence on fossil fuels; however, developers must carefully identify locations for energy projects to avoid unnecessary damage to California's vulnerable species and habitats. Utility-scale renewable energy offers significant challenges to balancing environmental protection with energy development due to the large land footprint of such projects.

A lack of baseline data, tools, and methodologies to assess and mitigate the interactions of species and habitats with renewable energy projects creates uncertainty and delays and increases the costs of permitting. A lack of shared information on the effects of renewable energy siting and deployment on wildlife species has created significant challenges for utility-scale solar development in southeastern California. Resource assessment and impact determination are difficult due to the lack of experience, information regarding how to adequately assess species distribution over square miles of desert, knowledge on population dynamics, and knowledge of species sensitivity to disturbance. This problem is exacerbated by a lack of proven mitigation measures and strategies. This issue, however, is not unique to large-scale solar projects, but also applies to other large-scale renewable energy sources such as wind farms, transmission lines, and forest biomass harvesting. Species and habitat considerations have also been major barriers to siting and deployment of other renewable energy technologies, including biomass and geothermal energy. There is a need for information and tools to not only to make the permitting process easier for these renewable energy technologies, but also to ensure environmental protection through developing, enhancing, and validating mitigation measures.

Bird, bat, and other animal deaths from collisions with power lines and wind turbines are an ongoing environmental issue, affecting wind energy and electricity development, and are a major challenge for siting wind energy projects throughout the state. A greater understanding of the status and movement patterns of birds and bats will allow for the development of appropriate and viable mitigation for the take of species at wind facilities. An example of this is the lack of information regarding the population status and viability of the golden eagle has led

to a cessation of take permits necessary for project development in the Desert Renewable Energy Conservation Plan (DRECP).

Large-scale biomass cultivation and harvesting in agricultural and forested areas may adversely affect wildlife species. Agricultural areas within the state support sensitive species, such as the Swainson's hawk, may be displaced if new agricultural crops for biomass production are introduced. Wildlife responses to forest biomass harvesting vary from species to species, but more information is needed to understand how each species will respond to different harvesting techniques and how to conduct harvesting sustainably.

Purpose: The intent of this initiative is to develop tools, technologies, and information that will help reduce, resolve, and anticipate environmental barriers to renewable energy deployment in California. Research on fossil fuel generation will also be addressed under this initiative. This initiative will emphasize resolving scientific data gaps and developing analytical tools related to sensitive terrestrial species and habitats to reduce delay and uncertainty in the siting process for energy facilities. Potential research topics include developing and testing innovative species mitigation strategies, building habitat suitability models and planning/management tools, and improving impact assessment protocols and scientific baselines. Under this initiative, tools to minimize environmental impacts can be tested and demonstrated through the pilot-scale stage.

Research under this initiative will also inform planning efforts, such as the Desert Renewable Energy Plan, to ensure environmental barriers to future energy deployment are proactively addressed and land-use conflicts minimized. Ratepayers benefit by achieving RPS goals with lower environmental impact, with mitigation focused on effective habitat strategies.

Stakeholders: Ratepayers, utilities, research institutions, NGOs, U.S. EPA, renewable energy developers.

Background: While a significant amount of research on the state's biological resources has been conducted, very little of this work has focused on applied research to address the environmental effects of electricity generation. Examples of research to inform the permitting process for energy development in California include efforts by the California Wind Energy Association, the U.S. Forest Service, and others to address avian and bat interactions with wind turbines; the U.S. Forest Service is addressing the effects of collecting forest biomass on song birds and small mammals; and the University of Redlands is developing a decision support tool for assessing and mitigating impacts to desert tortoises.

Nine current projects are addressing research to facilitate renewable energy siting and planning in the DRECP, as identified in the *2009 Integrated Energy Policy Report*. The DRECP will guide renewable energy siting and conservation in the Mojave Desert and Colorado Desert of California and is being developed by the Renewable Energy Action Team made up of the Energy Commission, California Department of Fish and Game (DFG), the U.S. Fish and Wildlife Service, and the U.S. Bureau of Land Management. These agencies, along with universities and other environmental stakeholders such as the Nature Conservancy, have recently invested in

targeted research to facilitate the DRECP. For example, in 2011 at least $1 million in federal funding was provided to the DFG for endangered species research related to the DRECP.

S5.3 Proposed Funding Initiative: Develop Analytical Tools and Technologies to Reduce Energy Stresses on Aquatic Resources and Improve Water-Energy Management.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X					X		

Issues: Water is closely intertwined with the state's electricity system. Not only is electricity used to pump, treat, use, and dispose of water, but water is also used in electricity generation. Hydropower, of course, uses water; most electric power plants use water for evaporative cooling as well.

As California's electricity system evolves to meet the state's renewable energy and GHG emission goals, it is important to reduce electricity's demand for water. Scarce freshwater resources may be a barrier to greater penetration of certain renewable energy technologies like CSP, geothermal, and biomass.

Opportunities for construction of new hydroelectric plants are extremely limited in California. Most economically viable sites have been developed, and developing remaining sites faces significant barriers. Because hydropower plays a significant role in the state's electricity system, there are significant opportunities from improved forecasting and decision support tools as well as an improved understanding of meteorological processes, such as atmospheric rivers that affect the amount and distribution of precipitation, runoff patterns, and hydropower generation.

As identified in the *2005 Integrated Energy Policy Report*, there is a need for research to reduce the effects of hydropower generation on California's aquatic ecosystems. California's inland fish populations have suffered a steep decline, in part due to hydropower generation. As existing nonfederal hydropower facilities are relicensed by FERC, there is a need for research to inform this permitting process.

Environmental concerns may also pose significant permitting issues for emerging marine renewable energy technologies such as wave energy devices or offshore wind. Wave energy devices may change near-shore sediment transport, adversely affecting near-shore benthic (sea bottom) communities. Fish are anticipated to use wave energy conversion installations as artificial habitat, so sound and electromagnetic fields from the technology may affect their

behavior. Large arrays of wave energy devices may block migratory marine mammal migration routes. Offshore wind anchoring devices may also block migrating marine mammals and cause bird and bat collisions with the wind turbines. It is important that these environmental effects be assessed and, where needed, be avoided, resolved, or reduced prior to commercial deployment of these emerging technologies.

Purpose: This initiative will develop tools, technologies, and information to inform the permitting and deployment process to help improve water and energy management. For example, there is a need to improve understanding of meteorological processes to increase the ability to forecast precipitation and runoff for hydropower generation. There is also a need to develop innovative forecasting techniques for high elevation hydropower, which represents about a third of California's hydropower capacity. For example, the Hydrologic Research Center has demonstrated the usefulness of probabilistic runoff forecasts at five low-elevation reservoirs in Northern California. This initiative would support application of probabilistic forecasting to other hydropower projects.

This initiative will also support research to help reduce the impacts of electricity generation, especially hydropower generation, on aquatic species and habitats as well. Three thousand MW of nonfederal hydropower generation in the state will be up for relicensing by FERC within the next 10 years. Since these licenses last 30 to 50 years, it is critical that the necessary tools and information be developed to inform this permitting process.

This initiative will also support research to reduce water demands from the electricity-generating sector. A major source of water consumption from fossil fuel and renewable generation is the water used for steam condensation, commonly referred to as power plant cooling. While there is water conserving cooling technologies available, such as an air-cooled condenser, which reduces water demand for cooling to zero, there are cost and performance penalties associated with their use. There is also a need for research to inform future renewable energy siting for offshore wind and wave technologies. Under this initiative, ecological information, tools, and methodologies will be developed to proactively determine potential environmental impacts prior to full-scale deployment of offshore wind or wave energy conversion technologies.

Stakeholders: Ratepayers, research institutions, NGOs, IOUs, Department of Water Resources, water management districts.

Background: The U.S. DOE, the Electric Power Research Institute, and others have researched ways to reduce water demand from electricity generation, specifically through the use of air-cooled condensers or the use of water sources not suitable for agricultural or municipal uses. Research on air-cooled condensers has sought ways to reduce the heat and wind effects on condensers while degraded water research addressed the challenges of using such water from different sources in power plant cooling towers. Research by John Maulbetsch and the

University of California, Davis, is assessing the best use of wind barriers to reduce wind effects on air-cooled condensers.

The University of California, Davis, the U.S. Forest Service, Garcia and Associates, and others researched the effects of hydropower ramping flows on aquatic ecosystems. H.T. Harvey and Associates has conducted an environmental knowledge gap analysis for wave energy development in California.

Research conducted by NOAA's Office of Atmospheric Research, the California Department of Water Resources, and the California Energy Commission has delineated the importance of atmospheric rivers, a weather phenomenon that delivers a significant portion of the precipitation and runoff that occurs in California.

S5.4 Proposed Funding Initiative: Develop Analytical Tools and Technologies to Plan for and Minimize the Impacts of Climate Change on the Electricity System.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations / Market Design	Generation	Transmission / Distribution	Demand – side Management
X					X		

Issue: Recent research has shown that over the next few decades the electricity system will be highly vulnerable to climate change and extreme events. The information generated so far, however, has been designed to estimate the seriousness of the impacts and has looked mostly at what would happen by the second half of this century. The rapid evolution of the energy system must also be taken into account given the ambitious GHG reduction goals adopted in California. This evolution should be guided with information that facilitates the creation of a more climate-resilient energy system. It is unlikely that programs other than EPIC would be able to generate the scientific and engineering information needed to create a more resilient electricity system for ratepayers in California.

Purpose: This initiative will produce practical information on GHG mitigation, impacts, and adaptation to inform policy deliberations at the CPUC, Energy Commission, and other jurisdictions. The focus will be on mitigation, impacts, and adaptation options for the next few decades since that is the period used to develop energy policy.

To better assess potential climate change effects on the state's electricity system, this initiative will improve climate change projections for California. Current climate change projections focus on temperature and precipitation with a very crude treatment of important variables such as wind and solar radiation. The proposed new research will improve the simulation of wind,

ground-level solar radiation, relative humidity, and other parameters of importance to the electricity sector and will refine projections of temperatures and precipitation that still contain significant uncertainties, especially on local-to-regional scales specific to IOU electricity systems in California.

This initiative will also improve the depiction of high-elevation hydropower units in water models under different climate scenarios. Current simulations address only low-elevation hydropower units. Including high-elevation hydropower units is essential because research shows that climate change would cause high levels of spillage from high-elevation reservoirs during the late part of the winter season, creating water management problems for low-elevation reservoirs and their associated hydropower units.

This initiative will also address the energy implications of adaptation measures. California has begun to identify and implement adaptation measures that may substantially affect energy generation and demand. For example, water agencies are investigating the use of natural groundwater reservoirs to store water during wet years and to lessen the effects of expected snowpack decline in the Sierra Nevada. The energy demand implications of pumping water from these groundwater reservoirs is unknown. Research to identify the energy consumption implications of different adaptation options under consideration now and in the future is also needed.

This initiative will also research the potential evolution of the electricity system and identify needed changes to the IOU electricity system that drastically reduce GHG emissions while avoiding or minimizing environmental impacts.

This initiative will use a practical approach by delving into engineering design issues for concrete steps that could be taken by electricity system managers. The research focus is on practical engineering applications that produce actionable products but will also look at economic issues, including econometric and economic experiments, as needed to fully evaluate mitigation and adaptation opportunities. For example, Pacific Institute research has shown that with sea level rise some coastal power plants will be in danger of coastal flooding. What is needed now are engineering studies to identify when the problem would materialize, what specific actions should be taken at these power plants, and what alternatives are available. The same can be said about effects of climate change on high-elevation hydropower units. Researchers have developed models that can adequately identify overall system impacts but are unable to generate practical local information that can be used to implement actionable adaptation measures at specific hydropower units.

Stakeholders: Ratepayers, research institutions, Air Quality Management Districts, ARB, CPUC, and IOUs.

Background: California leads the nation on climate change research. While there are national research efforts by different federal agencies, including the U.S. DOE and the National Academy of Sciences, they will not specifically address California and the unique challenges

that climate change will present to the state. NGOs have also expressed strong support for the spirit of this initiative in comments submitted to the CPUC by The Nature Conservancy, the Natural Resources Defense Council, the Union of Concerned Scientists, the Sierra Club, the Environmental Defense Fund, and others during the deliberations that culminated with the creation of EPIC.

Smart Grid Enabling Clean Energy

S6 Strategic Objective: Develop Technologies, Tools, and Strategies to Enable the Smart Grid of 2020.

Table 14: Ratepayer Benefits Summary for Strategic Objective 6

	Promote Greater Reliability	Lower Costs	Increased Safety	Societal Benefits	GHG emissions mitigation and adaptation	Lower emission vehicles/transportation	Economic Development	Public Utilities Code Section 740.1	Public Utilities Code Section 8360
S6.1 Develop Equipment and Technologies to Enable Power Flow Control and Bi-Directional Power Flow Through the Transmission and Distribution System.	X		X					X	X
S6.2 Develop Controls and Equipment to Expand Distribution Automation Capabilities.	X	X	X			X		X	X
S6.3 Develop Automation and Operational Practices to Make Use of Smart Grid Equipment.	X		X	X				X	X
S6.4 Develop Grid Operation Practices and Applications that Use Renewable Availability Data.	X		X					X	X
S6.5 Develop Smart Grid Communication Systems That Interface With Customer Premise Networks and Distributed Energy Resources.	X	X	X	X			X	X	X

Source: California Energy Commission.

Today's electricity grid was designed for centralized generation in which power flows in one direction from baseload power plants through the T&D systems and finally to the customer. As new technologies such as intermittent renewable resources, energy storage, DG, and PEVs are deployed into the system at higher levels, California's electricity grid will become more decentralized and complex. To manage this more complex system, electric grid operators will need improvements in grid communications, automation of T&D systems, standards and protocols, and other related areas to integrate these technologies optimally into a reliable, efficient, and flexible smart grid.

The California Legislature recognized the need for a smart grid and in 2009 passed the first statewide smart grid bill in the country. Senate Bill 17 (Padilla, Chapter 327, Statutes of 2009) directed the CPUC to set requirements for IOU smart grid deployment plans.

This objective will conduct R&D activities to help facilitate the successful implementation of these preliminary smart grid deployment plans by developing, testing and evaluating new and advanced technologies, tools, and strategies that can be further demonstrated and deployed by the IOUs.

Since 2003, the Energy Commission has collaborated with IOUs and the California ISO in the form of a standing research committee in the Transmission Research Program. This committee identified the highest priority issues for research within the California grid. An example of an identified research topic is synchrophasor research. This research has attained a high degree of success. A similar committee was formed for distribution system research. Today these committees are combined and provide advice and guidance on smart grid research activities. The Energy Commission has also held numerous public workshops on technologies considered for research.

Activities in the funding initiatives under this objective will be closely coordinated with the IOUs to ensure no duplication of efforts, and to provide a path to market for the research products of these initiatives. The market for smart grid technologies is very dynamic with research continuing across the nation and vendors continuing to develop product offerings. Coordinating the activities of the EPIC administrators and sharing information on recent developments in the research areas under this objective will inform and enhance the projects and their results.

Transmission and Distribution Upgrades for Smart Grid

To meet the Governor's goal of 20 gigawatts of renewable generation by 2020, the existing T&D system must be upgraded to handle high penetrations of distributed and renewable energy resources, increase grid reliability, and shorten the downtime when outages do occur. The existing T&D system lacks the infrastructure and technical sophistication to support this goal while maintaining high grid reliability. With limited capacity for two-way power flows and without control and communication at the point of use, California's existing distribution system

is not equipped to fully realize the benefits of DG. Upgrades will include modernizing T&D equipment, enhancing automated distribution systems, and improving control over DER.

Smart Grid Communications Systems

Utilities can improve electric service if they have a better understanding of the generators and loads behind the meter. This task becomes more difficult and complicated as more DG and electric vehicles are added because the net power from local generation and loads is combined together within a distribution circuit.

Incorporating local generator and load data from CPNs into smart grid communications systems will help operators address potential problem areas in the distribution system and respond with the appropriate operational modifications, helping to relieve grid congestion. Smart grid communications systems that are properly integrated with communications on the customer side of the meter will allow California electric ratepayers to have secure access to more information and options for electric services to lower their electricity costs.

In forming the initiatives to meet Strategic Objective S6, the Energy Commission reviewed the preliminary IOU smart grid deployment plans. The Energy Commission also considered the results from smart grid roadmaps prepared from the utility and industry perspectives. The gaps identified in these preliminary deployment plans and roadmaps were discussed with stakeholders through advisory board meetings for strategic-level advice on future research. A technical working group on smart infrastructure provided advice at the program level. Energy Commission staff facilitated workshops with stakeholders identified in the CPUC decision. These stakeholders identified the objectives and initiatives contained in this investment plan. Through this process, the Energy Commission developed smart grid initiatives that are not being adequately addressed in the competitive or regulated marketplace. These initiatives fit into the role of the CPUC and the Energy Commission. An example of an initiative outside the role of the CPUC and the Energy Commission was a recommended initiative for testing flame retardant clothing. This recommended initiative was considered but excluded for EPIC funding. Testing of safety equipment is best left to the federal government, the Occupational Safety and Health Administration, and other agencies that have that role. Other initiatives not considered for funding were initiatives dealing with standards development. In the U.S., there are many stakeholder-funded organizations such as IEEE, SAE, NEMA, and ANSI through whom standards are developed. While these initiatives were proposed, they were removed from this investment plan as there are already stakeholder funded groups developing standards.

S6.1 Proposed Funding Initiative: Develop Equipment and Technologies to Enable Power Flow Control and Bi-Directional Power Flow Through the Transmission and Distribution System.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations/ Market Design	Generation	Transmission/ Distribution	Demand – side Management
X				X	X	X	

Issue: Existing T&D equipment cannot handle the two-way power flow that occurs with DG connected at all levels in the electric system, from utility-scale storage down to a residential solar roof. The traditional design of the protection and control systems also prevents integrating high penetrations of DER at various connection points throughout the system. Recently developed and deployed smart grid-enabled devices need to be coordinated into a single system that can easily assimilate new smart devices over time.

Purpose: This initiative will advance the development and deployment of new technologies to modernize the electrical T&D system for an adaptable and controllable smart grid. Examples of proposed research topics include:

- Developing synchrophasor technology for the distribution system.
- Developing new products such as flexible, alternating current transmission system devices and other direct control power flow devices.
- Developing equipment and technologies to increase T&D circuit capacities.
- Developing new or improving existing equipment to react quickly enough to adapt to variable behavior of renewable generators and loads.

Stakeholders: Ratepayers who wish to install renewable energy generation, utilities, and electric vehicle owners.

Background: Past research on synchrophasors developed phasor measurement units to measure and transmit data about the transmission system to the California ISO. Early stage research on four-quadrant smart inverters, fault current controllers, and smart transformers is of interest to utilities. Existing distribution equipment such as switches, protective relays, capacitor banks, and voltage regulators cannot handle two-way power flow and will need to operate more frequently as more variable renewable generation, distributed energy storage, and electric vehicles are added to the grid. Inadequate T&D equipment is a critical barrier to renewable integration that must be overcome.

S6.2 Proposed Funding Initiative: Develop Controls and Equipment to Expand Distribution Automation Capabilities.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations/ Market Design	Generation	Transmission/ Distribution	Demand – side Management
X						X	

Issue: Existing distribution monitoring and control systems are not designed to manage high penetrations of distributed and renewable energy resources and cannot be used to control energy-smart communities and microgrids. In addition to addressing data resolution and communication issues, more information on the behavior of variable renewable resources is needed for monitoring and control systems. Renewable energy exhibits nontypical generator behavior that makes it difficult for grid operators to manage. At the same time, the increasing load of PEVs introduces more uncertainty for electric supply and demand.

Purpose: This initiative will enhance distribution automation to integrate DER and improve grid reliability. This research will develop new emerging technologies to increase the amount of renewables that can be connected at the distribution level and provide greater control over the operation of DER. Research will include methods to aggregate and control loads and DG, including PEVs, to improve grid reliability. Grid operators will have a greater level of confidence in providing reliable electric service with high penetrations of renewable and DG.

Examples of proposed research topics include:

- Developing synchrophasors for use in distribution systems.
- Developing technologies and strategies for T&D systems to handle renewable generation issues such as intermittency and voltage regulation.
- Investigating other functions of DG and distributed storage, individually or in combinations.
- Developing controls capable of controlling all of the functions within energy-smart communities and microgrids.
- Coordinating DG control between operators and energy aggregators.
- Determining the optimal aggregation of various types of DG, including PEVs.
- The utilities in their investment plans and their preliminary smart grid deployment plans have identified activities in the area of distribution automation. The activities in this

initiative will research and develop new technologies or applications not addressed in the utility plans such as synchrophasors for use on the distribution system. Activities in this initiative will be coordinated with the utilities to avoid duplication, and provide a path to market. Coordination of these activities with the utilities under this initiative will enhance the results of the research as it moves from applied research to demonstration and deployment.

Stakeholders: Ratepayers who operate microgrids, grid operators, utilities, and third-party aggregators.

Background: Utilities already have distribution management systems, but they lack the capability to respond fast enough to changes resulting from variable renewable generation at multiple connection points, including dispatching energy storage. Past research on synchrophasors on the transmission system successfully provided higher resolution data to the California ISO; therefore, the question for research is whether synchrophasor technology can be used to obtain detailed information about the distribution system. Other related barriers to enhancing distribution automation include managing large volumes of data and a lack of analysis tools to implement automated system changes.

One of the barriers to having a flexible grid is the inability to control DER and loads at the grid level. Multiple stakeholders must be involved in coordinating DG control to maximize grid capacity and flexibility. There has been limited research on methods to aggregate and control loads and DG, including PEVs, to improve grid reliability. However, schemes using intelligent software agents to aggregate load and generation and also wide-area management systems have undergone testing. Since 1996, various schemes for combining loads and electric vehicles have been proposed; however, none were implemented due to market barriers.

S6.3 Proposed Funding Initiative: Develop Automation and Operational Practices to Make Use of Smart Grid Equipment.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations/ Market Design	Generation	Transmission/ Distribution	Demand – side Management
X				X	X	X	

Issue: Grid operators lack the proper procedures for handling high penetrations of renewable resources because they do not know what to expect. The variety of characteristics of different types of renewable energy resources increases the complexity of operating the grid, especially as additional resources are connected. It is critical to have a comprehensive understanding of

the changes in grid operations needed as penetration of renewable generation increases over time.

Purpose: This initiative will develop automation and operational practices, including those for outage management, low system inertia, congestion mitigation, and infrastructure protection, to make use of smart grid equipment. Examples of proposed research topics include:

- Determining effects on transmission systems from operational changes in the distribution system associated with distributed energy resource integration.
- Enabling dynamic thermal ratings for transmission lines to increase load-carrying capacity.
- Establishing thresholds for system inertia and frequency response and methods for maintaining those thresholds.
- Investigating methods for sharing multiple resources, such as energy storage, between balancing authorities (California ISO and Bonneville Power Authority).

Stakeholders: Ratepayers, due to increased grid reliability and greater availability of renewable energy, and grid operators.

Background: Past research has attempted to characterize grid reliability issues such as instability and renewable intermittency, and further research is needed to understand their impacts on the grid. However, there appears to be less research on how to modify grid operations to handle these issues. The traditional approach is to build more infrastructure such as new generators, circuits, and wires, but this approach is no longer sufficient for an observable, controllable, and adaptable grid with high penetrations of renewables.

Energy Commission staff held Technical Advisory Committee (TAC) meetings with the IOUs and the California ISO over the past several years to discuss T&D research needs. TAC members have identified this research gap, which needs to be addressed to integrate high penetrations of renewable and DG on the grid. Another barrier to renewable integration is transmission congestion. Research on understanding which transmission lines would most benefit from dynamic thermal line ratings could help increase transmission capacity for renewable generation and under extreme conditions.

The California ISO identified a specific research barrier regarding real-time monitoring. Grid operators want to incorporate frequency response and inertia limits into their generation commitment and dispatch procedures, but they do not know what these limits are for maintaining grid reliability.

S6.4 Proposed Funding Initiative: Develop Grid Operation Practices and Applications That Use Renewable Availability Data.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations/ Market Design	Generation	Transmission/ Distribution	Demand – side Management
X				X			

Issue: Weather events can dramatically affect the power output of renewable wind and solar generation. The resulting fast ramping strains the grid infrastructure, and the ability of grid operators to reliably anticipate and react appropriately or automatically to these events does not yet exist.

Determining the availability of renewable resources using existing demand forecasting methods has forced operators to make many assumptions. Automated monitoring of the electrical system and increased use of smart metering has made it easier to collect large amounts of system data. The merging of internal utility data and all publicly available data can help utilities better understand the operations of the electric system and better meet customer needs. Developing ways to integrate forecast data, including weather events and demand forecasts, into automated operation systems is necessary to streamline grid operations. Modern analysis using data analytics has not been applied for grid operation of renewables. There is a need to define data applications, assemble the analytics, and produce data visualizations and operation protocols for utilities.

Purpose: This initiative will develop the best practices and applications in data analytics and select specific examples to demonstrate with the utilities and the California ISO. These best practices could be in better outage management, DER management, renewable integration, or customer load management.

Stakeholders: Ratepayers who own renewable generation, utilities, grid operators, and renewable energy providers.

Background: Utilities have been collecting monitoring data in databases for many years. Other large databases exist in the public domain (for example, weather, traffic, and earthquakes). Much of this data is not used because it cannot be easily merged. Recently, industry has ramped up efforts to use this data. These activities are known as "data analytics" and apply to a wide variety of industries. A certain subset of the available data would be relevant to utilities for the purposes of weather forecasting and demand forecasting. There are also several vendors making available products that can perform data analytics without significant custom programming.

Data analytics in the context of grid operation and demand forecasting is new and not suited to full-scale demonstrations in the near term. R&D activities under this initiative would allow all California utilities to leverage the best practices and develop the best applications. The long period for the deployment of these best practices and applications fits with the EPIC Program's time frame and mandate.

S6.5 Proposed Funding Initiative: Develop Smart Grid Communication Systems That Interface With Customer Premise Networks and Distributed Energy Resources.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations/ Market Design	Generation	Transmission/ Distribution	Demand – side Management
X						X	X

Issue: Utilities are concerned about protecting the distribution system, particularly when dealing with increasing amounts of two-way power flow from DERs and large varying loads. Microgrids and other off-the-grid sources may create a sudden overload on the distribution system if these sources malfunction due to equipment failure, local faults, or a temporary shortage of resources such that they cannot meet their demand and need power from the grid. Utilities need enough real-time information about customer electricity usage to address these issues.

Various technologies and smart devices/appliances can provide electricity use data; however, research is needed to determine a secure and reliable interface between customer-side-of-meter systems, such as CPNs and local energy storage, and the distribution system that is compatible with utility systems for more efficient power delivery based on customer demand.

Purpose: This initiative will develop smart grid communications systems that use CPN data, especially DER data. This information will give utilities a better understanding of actions "behind-the-meter" such as DG profiles and varying loads that may affect distribution operations. Monitoring the appropriate information from distribution-level renewable resources and loads will allow proper integration into the smart grid. Improving the smart grid communications system will also encourage aggregators to participate in California ISO markets. Examples of proposed research topics include:

- Developing and demonstrating communication interfaces between CPNs and the distribution system.
- Determining what distribution operations to modify and how to modify them based on information received from CPNs.

- Detecting low-level faults and other system anomalies.
- Reducing metering and telemetry costs of participants in California ISO markets.
- Filtering CPN and microgrid data and identifying pertinent information for grid operators.
- Designing control system to monitor and control DERs including energy storage.
- Disaggregate DG from loads.
- This initiative will develop the communications between inverters and CPNs to support the PV system hardware components and power electronics as discussed in initiative S3.3*: Develop Advanced Distributed Photovoltaic Systems to Reduce the Cost of Energy, Increase Interoperability, and Advance Plug-and-Play Capabilities.*

Stakeholders: Ratepayers who operate microgrids or otherwise have equipment that interoperates with their utility for sharing resources, utilities, grid operators, and third-party aggregators.

Background: Research in DR programs has resulted in the OpenADR protocol, which is now completed and commercially available. The research included interfacing with CPNs for industrial and commercial customers. This research by Lawrence Berkeley National Laboratory may be applicable for other programs to encourage participation in California ISO markets. Other protocols suitable for communications include SEP 2.0 and IEC 61850.

Past research on microgrids provides information on community-scale local generation and communications. The microgrid at the University of California, San Diego, is an example of a multibuilding system with local generation, energy storage, electric vehicle charging, combined heat and power, and various renewable technologies all integrated through one master controller.

S7 Strategic Objective: Develop Operational Tools, Models, and Simulations to Improve Grid Resource Planning.

Table 15: Ratepayer Benefits Summary for Strategic Objective 7

	Promote Greater Reliability	Lower Costs	Increased Safety	Societal Benefits	GHG emissions mitigation and adaptation	Lower emission vehicles/transportation	Economic Development	Public Utilities Code Section 740.1	Public Utilities Code Section 8360
S7.1 Determine the Characteristics of the Generation Fleet of 2020 for Grid Operators and Planners.	X	X			X		X	X	X
S7.2 Catalog Distributed Energy Resources to Improve Operator Dispatch and Visibility.	X	X			X			X	X
S7.3 Develop and Run Real-Time Scenarios to Support Operations, Including Energy Storage Utilization.	X	X			X	X	X	X	X
S7.4 Develop Interoperability Test Tools and Procedures to Validate New Subsystem Integration into the Grid.	X	X	X	X	X		X	X	X

Source: California Energy Commission.

To enable increasing penetrations of intermittent renewable energy into California's grid while maintaining reliability, a number of grid-operation tools, planning enhancements, and simulation tools need to be developed and implemented. Better models and tools are needed to evaluate the needs and characteristics of potential future energy fleets and incorporate them into future planning processes. Most scenarios will likely include increasing amounts of DER, including variable renewables. Increasing the visibility and dispatchability of these distributed resources will enable grid operators to more accurately predict resource availability and more efficiently operate the grid. Development and evaluation of real-time scenarios can further support efficient grid operations. Finally, it is essential to understand the operating characteristics of emerging energy resources before they can be integrated into the grid and incorporated into grid planning.

In light of California's stated clean energy goals, the composition of the 2020 grid will likely be greatly different from its current state. To understand what tools, technologies, and resources will be needed to ensure grid reliability, it will be essential to characterize California's potential

energy fleet for a number of future development scenarios. Better characterization of grid resources will enhance system visibility and allow for better modeling of the electricity generation fleet to create greater operational stability and robustness. This characterization will increase reliability and lower the costs of operation for utilities and ratepayers in California.

Providing grid operators with the ability to run real-time scenarios to support grid operations, including energy storage use, will allow grid operators to use the capabilities of smart grid equipment more effectively in everyday operation and thus improve the return on investments in smart grid infrastructure. Allowing operators to anticipate and react to disruptive events more effectively will also improve the resilience and reliability of smart grid operation. These advantages provide economic benefits to utility ratepayers by decreasing the costs resulting from fewer emergency response costs.

Developing interoperability test tools, models, and procedures to validate new subsystems into the grid will ensure the security, safety, and interoperability of grid equipment. This will result in fewer disruptive events and safety hazards, improving public confidence in and the cost-effectiveness of grid operations. Minimizing the deployment of proprietary, noncompatible subsystems will allow more companies to develop innovative grid infrastructure. A safe, interoperable, and secure infrastructure accelerates the adoption of renewable electrical generation.

In forming initiatives to meet Strategic Objective S7, the Energy Commission met with stakeholders through advisory board meetings and technical working group on smart grid research needs. Energy Commission staff also incorporated comments from the workshops held on its draft investment plan. Through this process, the Energy Commission developed smart grid initiatives that are not being adequately addressed in the competitive or regulated marketplace.

Since 2003, the Energy Commission has collaborated with IOUs and the California ISO in the form of a standing research committee on transmission and distribution issues facing utilities and grid operators. This committee provides advice and guidance on planning of grid resources.

S7.1 Proposed Funding Initiative: Determine the Characteristics of the Generation Fleet of 2020 for Grid Operators and Planners.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations/ Market Design	Generation	Transmission/ Distribution	Demand – side Management
X				X	X		

Issue: With the increasing adoption of variable and intermittent renewable generation, the operating characteristics of the grid have changed fundamentally. These characteristics are unknown and need research. The current fleet of generation equipment is a combination of legacy units and new additions with greatly varying characteristics of output capacity, fixed and variable costs of operation, geographical locations, load following capability, and dispatchability. There would be value in characterizing an optimal path for additions and alterations to the generating equipment fleet in California. California's ISO and utilities cannot determine the most cost-effective evolutions of California's generation fleet until a generation fleet model that accounts for interconnection and other factors is created.

Purpose: This initiative is for research to determine the characteristics of a cost-effective and robust generation fleet. A baseline and an "ideal" objective for the optimal evolution of the generation fleet needs to be established. Detailed models of present and possible future generation configurations will allow better evaluation of additions, modifications, and decommissioning activities as the generation fleet evolves.

Stakeholders: Grid operators, utilities, and ratepayers due to increased reliability and more cost-effective grid operations.

Background: Models currently provide information on different facets of grid operation and economics. They vary in the time scales, subsystems, and variables under investigation. Current models for renewables are simplistic and based on limited knowledge of the resources. These models must be augmented for a wider variety of applications and validated for use in generation fleet planning. They should take into account the impacts of current and projected fuel costs, plant commissioning and decommissioning activities, increasing renewable penetration, and energy storage including PEVs.

Allowing build-out, modification, and decommissioning decisions to proceed from a cost and operational standpoint will result in lower costs for utilities and ratepayers. New modeling capabilities will inform decisions for changes in the generation fleet, thereby supporting stable grid operation and robustness to benefit California's economy.

The Energy Commission is geared to administer research projects under this initiative because this initiative's objectives fit with the mandate and time frame of the EPIC Program. Generation fleet characterization is a California-wide activity covering multiple utility service territories, and it will be cost-beneficial and equitable for a nonutility entity to perform the fleet characterization activities.

S7.2 Proposed Funding Initiative: Catalog Distributed Energy Resources to Improve Operator Dispatch and Visibility.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations/ Market Design	Generation	Transmission/ Distribution	Demand – side Management
X				X		X	X

Issue: Many distributed energy generation resources are aggregated with loads on the customer side of the meter. This presents a problem for grid operators because the DG is often solar PV or wind that ramps up and down dramatically within seconds or minutes in response to weather events. The inability of operators to see proportions of load and generation on the distribution level greatly limits their flexibility and situational awareness. Operators need higher granularity of the DER to maintain service reliability.

Purpose: This initiative is for cataloguing characteristics of DER in California to allow utilities and the California ISO to operate with far more visibility. This requires cataloguing the location, size, and type of DG equipment and developing new tools using the database. The increased visibility of DG will improve operating characteristics and provide greater confidence in advanced planning for weather and demand events.

Stakeholders: Ratepayers due to increased service reliability, grid operators, and utilities.

Background: Probabilistic and historical decision support tools are used to plan generation dispatching, but these same tools could be used to greater effect if grid visibility is improved by cataloguing DER and disaggregating generation from load. The need to disaggregate generation from load is critical at this time as the penetration of fast-ramping DG such as solar PV is expanding. The uncertainty surrounding the minute-to-minute output of these generation sources would be reduced if they sources were accurately catalogued and matched to regional weather patterns.

Utilities will proceed with deploying their own grid modeling and operational tools in the future. These tools will be more effective once the utilities are furnished with data that accurately maps the locations and types of DER. Developing the methods to gather and compile this data is itself an activity that requires effort; therefore, it would be duplicative if each utility

mapped the DG in its own territory. It is more efficient and equitable for a statewide entity such as the Energy Commission to perform the generation mapping activities that the utilities will then leverage for grid operations.

S7.3 Proposed Funding Initiative: Develop and Run Real-Time Scenarios to Support Operations, Including Energy Storage Utilization.

Technology Pipeline Stage				Electricity System Value Chain			
Applied R&D and Pilot-scale Testing	Full-scale Demo	Early Deployment	Market Facilitation	Grid Operations/ Market Design	Generation	Transmission/ Distribution	Demand – side Management
X				X			

Issue: Utilities have limited visibility and control of grid system resources, including energy storage of various types, as well as distributed renewable generation. The inability of utilities to see and model various smart grid resources in real time, as well as the proportions of load and generation on the distribution level, greatly limits flexibility and situational awareness and degrades the robustness of the electric grid.

Purpose: This initiative will develop models and tools with real-time and automation capability to improve smart grid operations. These tools will provide grid operators with real-time assessments of the condition of the grid and a greater amount of control of T&D level resources. A possible research project under this initiative is to determine the "point of diminishing returns" for the granularity of grid visibility and control to ensure cost-effectiveness.

Stakeholders: Ratepayers due to more cost-effective grid operations and greater reliability, and grid operators due to having real-time assessments.

Background: Recent improvements in supervisory control and data acquisition, advanced metering infrastructure, geographic information systems, and computation can improve existing distribution models. This ability can tie together many data inputs in grid operation and enable distribution simulation and analytics. These models could very quickly run scenarios to show the effects of system planning or forecast weather to aid in real-time operation. The models can also be useful for future renewable and electric vehicle integration studies.

Significant effort will be expended in developing these models and tools, which California utilities will later use in planning and real-time operations. If each utility were to develop its own models and tools, there would be significant duplication of effort, and it would be inequitable if one utility were to develop models and tools that would then be applicable throughout California. Therefore, the Energy Commission, with continuous stakeholder input,