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ABSTRACT

The California Energy Commission manages public interest energy research for electric and natural gas research programs including the Public Interest Energy Research (PIER) Program. PIER supports energy-related research, development, and demonstration for research not adequately provided by competitive and regulated markets.

This report, prepared under Public Resources Code Section 25620.8, describes PIER electric funding and accomplishments in 2014, including activities and research projects funded from January 1, 2014 through December 31, 2014, ratepayer benefits, and program updates and initiatives.

Keywords: California Energy Commission, PIER, annual report, energy research, RD&D, energy efficiency, advanced generation, renewable energy, demand response, energy storage, buildings, distributed generation, transmission, smart grid, carbon sequestration, carbon capture, transportation, environmental, climate change, smart infrastructure, ratepayer benefits, public interest program, electricity, energy policy, loading order, jobs, clean energy, energy infrastructure, electric vehicles, greenhouse gas, Public Interest Energy Research Program, Renewables Portfolio Standard, building efficiency standards, California Public Utilities Commission

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EXECUTIVE SUMMARY

The California Energy Commission's Public Interest Energy Research (PIER) Program funds research, development, and demonstration (RD&D) projects as stipulated in Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006) to "develop, and help bring to market, energy technologies that provide increased environmental benefits, greater system reliability, and lower system costs." Research priorities are guided by California's loading order of preferred energy resources, which prioritizes Energy Commission research investment, first in energy efficiency and demand response; second, in renewable energy and distributed generation; and finally, in clean fossil fuel sources and infrastructure improvements. Research priorities are also guided by legislative mandates such as the Renewables Portfolio Standard (Senate Bill 1078, Sher, Chapter 516, Statutes of 2002), and the Global Warming Solutions Act of 2006 (Assembly Bill 32, Núñez, Chapter 488, Statutes of 2006), by plans such as the Energy Commission's *Integrated Energy Policy Report,* and by stakeholder input.

Investing in innovation is one of the most important pathways toward achieving California's clean energy future. Effective, policy-guided public interest energy research helps innovators and investors plan and design cost-effective solutions that will bring California into its low-carbon, diverse, efficient, and reliable energy future. Public interest energy research is an investment that yields significant benefits and lays the foundation for substantial savings into the future.

This annual report to the California Legislature, as required by Public Resources Code Section 25620.8, reports on the PIER Electric program in 2014, including specific information on award recipients, the amount of the awards, and the types of projects funded, along with an evaluation of the success of projects funded.

To date, the Energy Commission has invested more than $779 million for energy research and development through the PIER Electric program, leveraging its investment to attract more than $1.3 billion in match funding. Funded projects provide thousands of direct and indirect jobs to Californians, bolster California's status as a leader in energy innovation, and advance the state to a clean energy future.

Highlights of 2014 Research

The portfolio of research contained in this report demonstrates the significant advancements provided by public interest energy research efforts. Chapter 2 provides this information in full. Some of the research and benefit highlights are summarized here.

Energy Efficiency: It is often stated that the cheapest energy is unused energy. Energy efficiency research investigates the most effective strategies and technologies to reduce electricity use and demand in the state.

Energy efficiency RD&D projects made advancements in identifying technologies and strategies to increase building and facility energy efficiency. Research results show that **up to 90 percent improvement** in building air tightness can be achieved, reducing the loss of conditioned air and, consequently, the demand for cooling and heating. Heating, cooling, and ventilation

research continued to identify new strategies, including optimizing radiant heating and cooling systems, and developing cost-effective strategies for home renovations. The latter improvements can **reduce annual cooling energy use by up to 73 percent per home**, resulting in more comfortable and cost-effective buildings in California.

One project demonstrated a filtration system for use in wastewater treatment that can reduce energy used for aeration by up to 30 percent, increase plant treatment capacity by up to 30 percent, and increase biogas production by up to 25 percent. All of these will decrease wastewater treatment costs.

Renewables and the Energy-Environment Nexus: In 2014, the Energy Commission funded solar forecasting and distributed renewable energy projects, enabling further incorporation of renewables in California. Energy-related environmental research produced results and data of the environmental effects of energy production, delivery, and use. Research on identifying bird populations with migration events at or near wind energy facilities could increase wind energy production while protecting avian species.

Energy Infrastructure: Grid integration research demonstrated the benefits of holistically incorporating diverse renewable generation resources, energy storage, electric vehicles, and demand response into a utility grid. Research success with flow battery energy storage benefitted efforts to increase wider adoption of storage. In addition, transportation research highlighted a plug-in electric vehicle lithium-ion battery recycling technology.

Small Grant Projects: The Energy Innovation Small Grant Program funded proof-of-concept projects that yielded exceptional commercial success. One energy storage project from 2012 received $1.5 million in seed funding in 2014 as a result of Energy Commission support and a recently awarded project demonstrated a new navigation system for electric vehicles, which calculates travel routes that require the least amount of energy.

Highlights of 2014 PIER Portfolio Benefits

The 2014 PIER research portfolio provides diverse benefits to California ratepayers, often resulting in many additional benefits. Chapter 3 describes these benefits in full, and focuses on:

- Energy savings;
- Reduced grid capacity requirements;
- Cost savings;
- Grid reliability;
- Climate benefits;
- Local environmental and societal benefits; and
- Economic development.

PIER Program Update

In 2011, the Legislature did not reauthorize the electricity research portion of the PIER Program and the mechanism under Public Utilities Code Section 399.8 that funds it, the Public Goods Charge. As a result, the PIER Electric program encumbered the final PIER electricity funds in June 2013, and the Energy Commission will continue to manage the remaining active projects through the end of 2015. Following the close out of the PIER Program, the Energy Commission will release a Final Report, which will showcase the benefits of the entire PIER Electric Program since its inception in 1997.

In December 2011, the California Public Utilities Commission (CPUC) adopted the Electric Program Investment Charge (EPIC), which authorizes collecting funds from system benefits charges for renewables and research, development, and demonstration purposes, filling the gaps in funding from the expiration of the Public Goods Charge. In November 2013, the CPUC approved the first triennial EPIC investment plan submitted by the Energy Commission and the three investor-owned utilities. The proposed 2015-2017 triennial EPIC investment plan is currently awaiting approval by the CPUC. EPIC will be implemented consistent with program direction in Senate Bill 96 (Committee on Budget and Fiscal Review, Chapter 356, Statues of 2013).

Publicly administered RD&D ensures transparent and accountable data and research results, a balanced portfolio, maximum leveraging of funds with private, public, and government entities, and direct accountability to the public, ratepayers, and the legislature.

CHAPTER 1:
Introduction and Overview

The Power of Energy Innovation

Economic vitality and social well-being depend upon affordable, safe, environmentally friendly and reliable energy. The way society uses energy has evolved radically and has transformed the modern world, both economically and physically. Energy markets are vastly different today than they were just a few years ago; the use of finite fossil fuels has created environmental problems as well as investment risks and uncertainties. For these reasons, investing in energy innovation is critical to a bright future for California and the world.

For example, an electric system powered mainly by natural gas, oil, coal, or hydropower has little need for advanced storage technologies. Conversely, energy from renewable sources, like solar and wind, cannot be stored in a barrel or tank; it must either be used immediately or stored using advanced batteries, compressed air storage, hydroelectric storage, or other methods, many of which are relatively complex and unproven. Increasing the reliability and availability of energy from renewable sources to California's electricity grid will require significant innovation in energy storage technologies and in the ability to handle large-scale deployments.

Modernizing and improving energy systems preserves resources, creates jobs, increases reliability, reduces operating costs, and can solve environmental problems. California's elected representatives have set leading edge goals to significantly improve efficiency, reduce global warming emissions, and increase renewable energy use, among many others. The deadlines for meeting these goals are quickly approaching. New administrative and legislative policies, along with a growing level of funding sources, point toward a diverse and attainable low-carbon energy future. The sheer scale of the challenge will require intense coordination between technical, economical, and political realities.

For California to achieve set standards, energy innovation and infrastructure investments

The Role of Public Interest Energy Research

While public interest energy research alone cannot drive the investment in Energy innovation, the role of such research is indispensable. The California Energy Commission's Public Interest Energy Research (PIER) Program has invested in electricity research, development, and demonstration (RD&D) in energy efficiency and demand response, renewable energy resources, advanced electricity generation, transmission and distribution, energy-related transportation, and energy-related environmental research.

Public policy agents have an inherent responsibility to invest in energy research for several reasons. First, energy infrastructure decisions have a broad effect on public safety and the economy. Communities and businesses on the East Coast were left without power for weeks, in

some cases months, after "superstorm" Hurricane Sandy in October 2012. This event was one of many recent examples of the vulnerability of centralized and interconnected electric grids. In 2013, multiple news articles reflected on Hurricane Sandy and emphasized how the storm "could prove to be a turning point in how people think about the way electricity is produced and distributed,"[1] drawing attention to the importance of strengthening system resiliency and "pushing states to accelerate spending on smart grid[2] technology and distributed energy."[3]

The PIER Program addressed energy infrastructure vulnerabilities by investing in electric grid solutions that have significantly improved reliability such as PIER-funded smart grid and microgrid projects at a university campus, at the state's third largest jail, and in partnership with an investor-owned utility. These field demonstrations illustrate that improved energy systems can reduce pressure on the electric grid and provide greater energy security in the event of outages by operating independently. Advancing these solutions will help reduce the impacts of electric system disruptions in California by providing all customers with more reliable service.

Second, California has a unique influence on energy decisions made elsewhere due to its status as one of the largest and most innovative economies in the world. California's efficiency standards and environmental policies, and the technological advancements produced by its hubs of innovation, have verified many times over the saying "As California goes, so goes the nation." Raising the bar for energy efficiency, safety, and reliability for California ratepayers often leads to a desire by other states to emulate what California has accomplished.

Figure 1: The Energy Innovation Pipeline Brings Technologies to Market

Source: California Energy Commission

The Energy Innovation Pipeline (Figure 1) demonstrates the process that brings the products of energy research to users through the marketplace. Public interest energy RD&D must align with

1 Magill, Bobby. 2013. "Microgrids: Hurricane Sandy Forced Cities to Rethink Power Supply." *Huffington Post*. http://www.huffingtonpost.com/2013/09/09/microgrids-hurricane-sandy_n_3895982.html.

2 The U.S. Department of Energy defines the smart grid as "a class of technology people are using to bring utility electricity delivery systems into the 21st century, using computer-based remote control and automation. These systems are made possible by two-way communication technology and computer processing that has been used for decades in other industries" (see http://energy.gov/oe/technology-development/smart-grid for more information).

3 LaMonica, Martin. 2013. "One year later, Hurricane Sandy fuels grid innovation." *GreenBiz*. http://www.greenbiz.com/blog/2013/10/24/one-year-later-hurricane-sandy-fuels-grid-innovation.

new regulations and public investment to overcome the many barriers faced by new energy technologies. RD&D is the crucial link between innovators with ideas and investors with capital.

The PIER Program supports higher-risk research with the potential for providing far reaching public benefits, thus reducing the financial risk to the innovator by helping to demonstrate the technical merit of new ideas, products, and concepts. PIER is also breaking down market barriers through permit streamlining, incentives, goals and standards, and by making new technologies directly available to customers. Research improves productivity and lowers costs, which fosters economic growth. Nobel laureate Robert Solow estimated that more than 90 percent of economic growth comes from investments in innovation.[4]

RD&D tends to be a higher-risk, delayed-return investment, which can make financing and management support hard to obtain. In addition, capital markets prefer short-term return on investment, and even venture capitalists expect to see profits within three to five years.[5] It is common for research benefits to peak well over a decade after the initial research.[6] Therefore firms may invest less than what would be optimal for them and far less than what would be optimal for society. In addition, private research incentives do not always align with public policy goals, and managers and investors are offered incentives to seek short-term results.

Because consumers reap the rewards of RD&D in improved products and reduced costs and because RD&D projects can educate and change entire industries, the public rate of return for RD&D has been estimated at three to four times the private rate of return.[7] This is particularly relevant in the domain of energy, where failures of delivery can cost ratepayers billions of dollars. However, the value of reliability is hard to incorporate in the price of electricity.

Innovation in energy efficiency faces barriers such as communicating the technical nuances of new products and processes to the user so that they are able to understand and realize the

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4 Cited by D. M. Kammen in testimony to Congress. 2008. "Investing in the Future: R&D Needs to Meet America's Energy and Climate Challenges."

5 Weiss, Charles; Bonvillian, William. 2009. "Structuring an Energy Technology Revolution." Massachusetts Institute of Technology.

6 Research enhances the knowledge stock creating benefits over a long period. Alston et al. estimated the time stream of productivity gains from agricultural research and found the peak effect occurred around 24 years after the research.
Alston, J.M.; Andersen, M.A.; James, J.S.; Pardey, P.G. 2008. "Persistence Pays: U.S. Agricultural Productivity Growth and the Benefits from Public R&D Spending." InSTePP and Giannini Foundation Monograph. University of Minnesota, St. Paul and University of California, Davis (in preparation). Referenced in http://ageconsearch.umn.edu/bitstream/50091/2/p08-14.pdf and in http://www.landfood.unimelb.edu.au/info/seminars/2009/Alston-MelbourneUniversity-Deans%20Lecture-03-04-2009.pdf.

7 Nemet, Gregory F. "Policy and Innovation in Low-Carbon Energy Technologies." Ph.D. dissertation, May 2007. https://mywebspace.wisc.edu/nemet/web/Thesis.html

benefit of them, such as split landlord/tenant incentives. Often, the individuals procuring energy for firms are not generally those making business decisions. As a result, U.S. energy firms invest only 0.2 percent of their revenues to research, far less than the 10 to 20 percent invested in the information technology and pharmaceutical sectors, or the 3 percent U.S. industry average.[8]

Economic studies place the optimal energy research investment at 2 to 10 times what is invested today,[9] creating a clear justification for co-funding. Demonstration and pilot projects are also needed so that firms developing new energy technologies can reduce costs, improve reliability, and create a process for procurement and construction. However, a private firm that engages in development and demonstration may find itself sharing benefits with its competitors[10] and may be reluctant to invest in projects without public help. The International Energy Agency noted, "Buildings sector companies are unlikely to fund costly, high-profile demonstrations; they feel the government should play a role in leading these exhibitions" and in creating "public outreach and education around behaviors and information management to maximize building energy efficiency."[11]

Funding RD&D that meets ratepayers' energy needs will also help local economies. A 1993 study of patent citations showed that "inventors that work near important sources of new ideas benefit significantly sooner from their spillovers," with six times more innovation (as measured by patent applications) in the metropolitan areas around new patents than could have been predicted by the concentration of inventors alone.[12] The Energy Commission's Energy Innovations Small Grants program has had considerable success attracting venture capital; private, nonutility, subsequent investment has exceeded the Energy Commission's investments fiftyfold. In fact, research has shown that out of all the public options for spending related to clean energy, private venture capitalists value their public counterparts most highly, and they recognize the value of public RD&D.[13]

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8 International Energy Agency (http://www.iea.org/papers/2010/global_gaps.pdf) citing National Science Board, Science and Engineering Indicators 2010.

9 Weiss and Bonvillian, *Structuring a New Energy Revolution*, cite many of these.

10 Economic and Technology Advancement Advisory Committee. 2009. "Advanced Technology to Meet California's Climate Goals: Opportunities, Barriers & Policy Solutions."

11 International Energy Agency. op cit.

12 Jaffe, Adam B. 1998. "Patents, Patent Citations, and the Dynamics of Technological Change." *National Bureau of Economic Research.* http://www.nber.org/reporter/summer98/jaffe_summer98.html., citing work the author collaborated in:
Jaffe, A.B., R. Henderson, and M. Trajtenberg. 1993. "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations." *Quarterly Journal of Economics* CVIII (3) (August): 577.

13 "Which renewable energy policy is a venture capitalist's best friend? Empirical evidence from a survey of international clean tech investors." *Energy Policy*, Volume 37, Issue 12, December 2009, Pages 4997–5006. http://www.sciencedirect.com/science/article/pii/S0301421509004807

Energy infrastructure decisions have a broad effect on public safety and the economy. Public sector leaders have an inherent responsibility to encourage investors to support RD&D which balances public need with technological advancements and reduces innovation barriers and financial risks for private investors. Leaders must enact policies and regulations that encourage innovation and set attainable goals that stimulate jobs and investments in California.

Report Structure

The Energy Commission's *Public Interest Energy Research 2014 Annual Report* describes 2014 PIER Electric program accomplishments and benefits. Chapter 1 provides an introduction to the program and an overview of the policies guiding the Commission's public interest energy research. Chapter 2 describes major research programs and highlights selected electricity research projects and their benefits. Chapter 3 presents an overview of the benefits of PIER's 2014 research portfolio and details in-depth benefits analyses for selected projects. Chapter 4 concludes with PIER's legacy. Appendix A lists the electricity-funded RD&D projects that were active or completed in 2014, and finally, Appendix B describes the methodologies used in the analysis of RD&D project benefits.

Policy, Planning, and Program Overview

As the state's primary energy policy and planning agency, the Energy Commission makes assessments and forecasts that aid in the development of energy policies that conserve resources, protect the environment, ensure energy reliability, enhance the state's economy, and protect public health and safety. The Commission supports California's energy policy and planning needs and fulfills the provisions of Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006) by conducting research that:

- Supports technology development to enable future building and appliance efficiency standards.
- Increases energy efficiency in major energy end-use sectors, including buildings, industrial, agricultural, and water sectors.
- Develops and integrates renewable energy into the state's electricity and natural gas systems.
- Funds needed advancements in smart grid and energy storage technology.
- Supports energy-related environmental research and transportation energy research directly tied to energy generation, transmission, and use.

The Energy Commission's administration:

- Provides transparency and accountability for all funds and projects.
- Conducts coordinated research to avoid duplication.
- Provides independent and impartial evaluations of proposals and projects.

- Supports RD&D work with a statewide, policy-focused interest dedicated to benefiting California ratepayers.
- Generates research opportunities for California-based companies that create jobs and stimulate the economy.
- Fosters critical relationships with California's universities, national laboratories, and high-tech companies that have diverse and substantial research capabilities.
- Leverages funds with private sources and the federal government.
- Works closely with the Legislature to ensure the program is operating to fulfill statutory goals.

Achieving the Vision for California's Electricity Future

Policymakers have crafted a vision for California's electricity future that is vastly different from its present. Through laws, ordinances, regulations, and standards, the blueprint for this vision has emerged.

The Vision for California's Future:

California's electricity future to 2030 and beyond will be characterized by highly efficient buildings, industries, and businesses; energy generation that is low-carbon, sustainable, and distributed; and a reliable, flexible transmission and distribution infrastructure.

Table 1 summarizes some of California's major energy policies and standards. PIER funding decisions support achievement of these goals without sacrificing safety and reliability.

Table 1: Select Policy Goals for California's Energy Future

Policy or Standard	Goal
Governor Brown's Clean Energy Jobs Plan	California should produce 20,000 new megawatts (MW) of renewable electricity by 2020, 12,000 MW of distributed energy, and 6,500 MW from CHP.
California's Loading Order, from the California *Energy Action Plan*	Prioritizes Energy Commission research investment first in energy efficiency and demand response; second, in renewable energy and distributed generation; and finally, in clean fossil fuel sources and infrastructure improvements.
Executive Order B-18-12 Greening State Buildings	Calls for efficiency improvements in new or renovated state buildings larger than 10,000 square feet; sets zero-net-energy (ZNE) and greenhouse gas (GHG) reduction goals.
Integrated Energy Policy Report	The Energy Commission's biennial energy forecasting and assessment report (required under Senate Bill 1389 of 2002) recommends policies to foster the development of energy efficiency, renewable energy, and more.
Assembly Bill 32 (2006) The California Global Warming Solutions Act	Requires the state to reduce GHG emissions to or below 1990 levels by 2020.
CPUC *Energy Efficiency Strategic Plan*	Sets efficiency goals, including ZNE goals for new homes by 2020 and for new commercial buildings by 2030.
Senate Bill X1 2 (2011) The Renewables Portfolio Standard	Requires all electricity retailers to meet 33% of their retail sales with renewable energy by 2020.
Senate Bill 17 (2009)	Mandates implementing and planning a smart grid.
Governor Brown's Executive Order B-16-2012 and the *2013 Zero Emission Vehicle Action Plan*	The Governor's Executive Order sets a long-term target of reaching 1.5 million zero-emission vehicles on California's roadways by 2025 and directed state agencies to "encourage the development and success of zero-emission vehicles." The *2013 Zero-Emission Vehicle Action Plan* identifies specific strategies and actions to meet this goal.
Senate Bill 1250 (2006)	Made provisions for efficiency and renewables research, declaring that it is in the best interests of the people of California that environmentally sound, safe, reliable, and affordable energy services and products be developed and that the PIER Program makes research investments to this end.
Assembly Bill 2514 (2010)	Establishes an energy storage target of 1,325 MW by 2020 for investor-owned utilities.
Governor Brown's State of the State (2015)	By 2030, California should increase its electricity derived from renewable sources to 50 percent, reduce petroleum use in cars and trucks by up to half, and double the efficiency in existing building and make heating fuels cleaner.

Source: California Energy Commission

Research Challenges Facing Policy Goals

Since its creation in 1996, the PIER Program has followed policy priorities to make funding decisions, effectively ensuring that California's energy goals are met. The diverse and ambitious goals created by California's Legislature and Governor face significant hurdles that are addressed by broad and strategic energy research.

The Breadth and Scale of the Vision: With deadlines for efficiency, renewable energy, smart grid, bioenergy, greenhouse gas emission reductions, and many other energy goals quickly approaching, public interest energy research in these areas helps ensure each goal can be met. The PIER Program public research funding initiatives were developed openly with relevant stakeholders.

The Need for Coordination: Achieving the vision required coordination between:

1) Efforts to improve different electricity technologies and practices that will ultimately be used together in the end-use sector, such as lighting, building envelope, and heating, ventilation, and air conditioning.

2) Innovators, investors, regulators, electricity providers, and policy decision makers to share energy research results and to ensure expectations and goals are kept realistic and efficient. Public interest energy research provided transparency that promotes coordination.

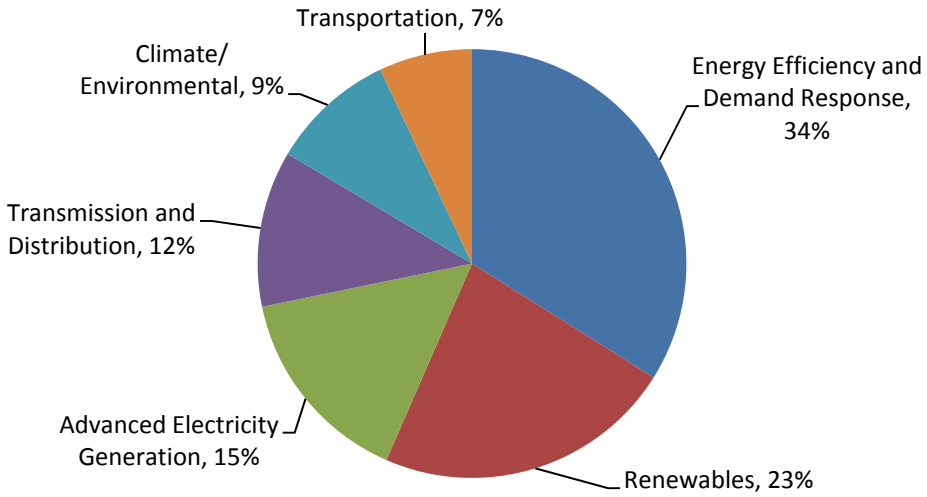
The Need for Directed Investment: Innovations often face uncertainty. Emerging technologies lack the benefit of economies of scale and often need public as well as private investment. With its record of attracting match funding many times greater than its own funding levels, PIER acted as a funnel for investment into technologies with a high potential for providing benefits and supporting public policy goals.

Making Connections to Market Success: Energy technologies and practices must often be deployed at scale within static infrastructure systems, are often part of regulated markets, and can be greatly influenced by social behavior. Thus, the success of a well-established and low-cost technology is often uncertain unless it is directly incorporated into existing energy standards, incentive programs, workforce training programs, or other broad pathways to market. PIER has successfully implemented the Energy Innovation Pipeline to bring research results to market, which benefits innovators, electricity providers, and ratepayers.

Program Funding Overview

Since the beginning of the program, PIER has prioritized projects to align with California's loading order. By consistently funding research based on the priorities of the loading order, the Energy Commission has ensured that energy investments are made where they are most needed to achieve electric system efficiency, generation, and delivery goals. Figure 2 illustrates PIER funding from 1997 through 2014, highlighting its alignment with California's energy policies.

Figure 2: Energy Commission 1997-2014 RD&D Funding Aligns with California's Energy Policies



The Energy Commission encumbered over $911 million for RD&D projects since 1997.
Source: California Energy Commission

Bringing Federal Funds to California: The Energy Commission's PIER Program has invested more than $911 million in electric and natural gas RD&D projects and leveraged these investments to attract more than $1.3 billion in match funding. More than 81 percent of this investment consisted of PIER electric funds.

In total, Commission RD&D projects have brought $639 million in American Recovery and Reinvestment Act (ARRA)-related match funds to California since 2010 at a cost of only $14.9 million of Commission administered funds. This resulted in not only an enormous investment in energy innovation at a minimal cost to California's ratepayers, but in advancements in crucial energy research areas. For example, ARRA funds supported more energy storage demonstrations in California than have ever been funded at one time in history.

Money Spent in California: According to PIER records, for active and completed projects in 2014, 85.5 percent of total research funds were spent in California. This large percentage of in-state PIER funds emphasizes that publicly funded energy research stimulates economic activity and growth in California.

Public Outreach Strategies

Over the years, the PIER Program has matured and evolved to respond to stakeholder input, developing administrative activities in support of research efforts and enhancing the program. In 2014, the Commission expanded outreach and dissemination of research information to the public through various channels. The Commission's blog[14] has highlighted many RD&D-funded

14 California Energy Commission Blog: The Official Blog of the Energy Commission. http://www.calenergycommission.blogspot.com/.

projects, sharing success stories of commercially available products and providing an easy-to-understand overview of highly technical PIER research.

In addition to increased social media outreach, the Commission organized and participated in ribbon-cutting events in 2014 that showcased successful PIER-funded research projects:

- On April 22, UC Davis conducted a ribbon cutting ceremony for its Renewable Energy Anaerobic Digester in Davis. The completion of construction and full operation of the UC Davis anaerobic digester was a major milestone under a PIER and ARRA cost-share-funded project. The event marked the official unveiling of the 50 tons-a-day anaerobic digester, gathered a wide range of stakeholders from industry, government agencies, and academia, and disseminated the values of renewable energy, multi-agency collaboration and benefits.

- On May 8, Southern California Gas Company (SoCalGas) joined with the Energy Commission to unveil the Hyperlight® Ultra Low-Cost Solar Thermal Technology at San Diego State University (SDSU) in Brawley. This low-cost, utility-scale concentrated solar power technology uses reflectors in long transparent plastic tubes resting in shallow ponds to reflect sunlight onto a heat collecting element centered above the array of tubes. With this design, Hyperlight can be economically installed on a wide range of terrain and land types.[15] Event speakers included Commission Chair Robert Weisenmiller and representatives from SoCalGas, Hyperlight Energy, and staff from SDSU.

- On May 22, a grand opening and ribbon cutting ceremony for EnerVault's Iron-Chromium Redox Flow Battery energy storage system was held in Turlock. EnerVault's system results in four hours of storage—the largest flow battery in the world. This storage system is fully integrated with a 150-kilowatt (kW) photovoltaic system for powering an irrigation pump located in an almond orchard (see Chapter 2 for more details on the project, titled *Integrating Flow Battery Storage Into the Smart Grid for Renewable Energy Applications*). This event was a significant achievement for the storage industry in demonstrating and scaling up the capability of long duration energy storage. The grand opening ceremony included speakers from California Independent System Operator (California ISO), EnerVault, U.S. DOE, the Chair of the Energy Commission, and others representing the energy storage industry and local governments.

The Commission continued to hold research forums to share project results, promote collaboration, and seek input on the most valuable next steps. Additionally, as part of contract fiduciary oversight, staff performed site visits to PIER-funded projects to ensure projects met program expectations. Examples of site visits included:

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15 For more information on this project, see Chapter 2 of the *Public Interest Energy Research 2013 Annual Report*:

Mirviss, Lillian. 2014. *Public Interest Energy Research 2013 Annual Report.* California Energy Commission, Energy Research and Development Division. Publication Number: CEC-500-2014-035-CMF.

- California Lighting Technology Center (UC Davis)
- El Dorado Irrigation District (El Dorado County)
- Electric Vehicles International (Stockton)
- Central Marin Sanitation Agency Waste Water Treatment Plan (Marin County)
- Beale Air Force Base (Yuba County)
- Camp Pendleton Naval Base (San Diego County)
- West Village Renewable-Based Energy Secure Community (UC Davis)
- Altamont Wind Farms (Tracy)
- Santa Rita Jail (Alameda County)
- Western Cooling Efficiency Center (UC Davis)
- Demand Response Research Center (Lawrence Berkeley National Laboratory)
- California Plug Load Research Center (UC Irvine)
- Linda County Water District (Kennedy Jenks Project, Olivehurst)
- Stockton Laboratory Homes (Wilcox Project, Stockton)

Staff met with representatives from around the world, including the Brazilian Water/Wastewater Energy Efficiency Delegation and the members of the JTI-Swedish Institute of Agriculture and Environmental Engineering, to discuss technologies and conservation practices as well as share ideas about energy research and demonstration.

Additionally, staff met with representatives from Korea, Japan, and France to discuss advancements in smart grid and microgrid technologies.

The Commission also presented project results through project reports and informative fact sheets. In 2014, the Commission published 134 final project reports on the Commission website.[16]

16 All reports are published online at: http://www.energy.ca.gov/research/reports_pubs.html.

Figure 3: Public Engagement in 2014

In 2014, the Energy Commission continued its outreach and awareness efforts. This figure shows a site visit to an Altamont wind farm for a PIER project, where staff and researchers discussed the benefits and potential future applications of research.

Source: California Energy Commission

PIER Program Status

As stated, the Legislature did not reauthorize the electricity research portion of the PIER Program and the mechanism under Public Utilities Code Section 399.8 for funding it, the Public Goods Charge. All active PIER electric-funded projects are being managed through 2015 as the program winds down and continues the transition to the Electric Program Investment Charge.

New Electricity RD&D Program

Recognizing the importance and benefits of public interest energy research, Governor Jerry Brown requested in 2011 that the CPUC take action to ensure that programs like those supported by the Public Goods Charge are instituted under CPUC authorities and take into account the constructive ideas for program updates that were identified during the legislative process. The CPUC adopted the Electric Program Investment Charge (EPIC) in December 2011, authorizing the collection of system benefits charges for renewables and research, development, and demonstration purposes. In November 2013, the CPUC approved the first triennial EPIC investment plan submitted by the Energy Commission and the three investor-owned utilities, and the proposed 2015-2017 triennial EPIC investment plan is currently awaiting approval by the CPUC.[17] EPIC will be implemented consistent with program direction in Senate Bill 96 (Committee on Budget and Fiscal Review, Chapter 356, Statues of 2013).

As part of EPIC, the Commission submits an annual report to the CPUC and the Legislature detailing program activities and highlighting funded projects. The *2014 EPIC Annual Report* provides information on the first investment plan, as well as status updates on EPIC-funded activities.[18]

17 More information on EPIC is available at http://www.energy.ca.gov/research/epic/.

18 The EPIC Annual Report is available at: http://www.energy.ca.gov/research/annual_reports.html

CHAPTER 2:
Public Interest Energy Research Delivers Technical Advancements

This chapter provides an overview of the research in the three major areas of the Public Interest Energy Research (PIER) program: energy efficiency, renewable energy, and energy infrastructure. It includes a short description of each program area, followed by illustrative research highlights for projects active or completed in 2014, describing the issue addressed, project details, and benefits. Overall, the RD&D projects make up a comprehensive portfolio of promising research that will return benefits to California electricity users.

Energy Efficiency Research

California's building, industrial, agriculture, and water sectors consume more than 90 percent of the state's annual electricity. As the state's population grows and the demand for energy increases, energy efficiency continues to be an important strategy for reducing energy use and cost, peak demand, GHG emissions, and other harmful impacts associated with the inefficient use of energy. Efficiency is at the top of California's loading order, prioritizing investment in efficiency above other strategies. Since "energy efficiency is the least cost, most reliable, and most environmentally sensitive resource and minimizes our contribution to climate change," it is the resource of first choice.[19]

California has historically been successful in keeping per capita energy use low as population has increased. Many modern energy efficiency challenges are related to changes in the way people use energy. Consumer electronics such as televisions, cable boxes, personal computers (including notebooks and tablets), smart phones, and other plug-in devices are quickly becoming a greater portion of overall use. Advanced technologies are powering globalization and economic opportunity, but modern data centers and other information technology support systems use a significant amount of energy. Addressing these challenges through efficiency, using both common sense and highly advanced technologies, will allow California's innovation economy to continue to grow, unburdened by energy costs and energy supply limitations.

The Golden State has long set the gold standard for efficiency and was the first state to enact building and appliance energy efficiency requirements. PIER's energy efficiency research and demonstrations have helped prove the viability and cost-effectiveness of measures like smart lighting controls and set the stage for measures included in the state's *2013 Building Energy Efficiency Standards* as well as future building and appliance efficiency standards.

PIER's contribution to changes in these standards directly addresses an issue important to consumers. A 2011 Consumer Federation study about public attitudes toward energy and

19 *California Energy Efficiency Strategic Plan, 2011 Update:* http://www.cpuc.ca.gov/NR/rdonlyres/A54B59C2-D571-440D-9477-3363726F573A/0/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf.

appliance efficiency standards concluded that nearly all Americans (95 percent) support efficiency increases, and that "the public overwhelmingly believes that improving appliance energy efficiency is beneficial and strongly supports appliance efficiency standards. Those people who are aware of minimum efficiency standards set by the government support them. They are willing to pay more for the product knowing that the additional cost will be made up over time in lower energy bills, and that they will ultimately save money."[20] The Energy Commission's efficiency research supported and contributed to improved building and appliance efficiency standards which led the path to developments in energy efficiency in the private market.

Continued energy efficiency improvements are essential to meeting the state's energy efficiency and GHG reduction goals. PIER's Energy Efficiency program area focused on developing and demonstrating technologies, strategies, and tools that will lay a foundation for a highly efficient future.

Buildings End-Use Efficiency Research

The buildings end-use efficiency program sponsored research that led to cost-effective performance and energy efficiency improvements in new and existing buildings and their associated components and structures (such as street and parking lot lights), equipment, appliances, and consumer electronics. The program focused on major energy-using systems, including lighting, HVAC systems, consumer electronics, and associated/related systems:

- New and improved products.
- Energy-efficient designs, materials, building techniques, and tools.
- Improved performance and efficiency standards for buildings and equipment.

20 Consumer Federation of America. 2011. *Public Attitudes Toward Energy Efficiency and Appliance Efficiency Standards: Consumers see the Benefits and Support the Standards.*

The Project: Renovating Homes to Increase Efficiency and Reduce Energy Consumption

The Issue: California's *2013 Building Energy Efficiency Standards* for residential buildings are widely respected as the most aggressive and innovative standards in the United States. However, they are applicable primarily to new construction. Because most California homes were built using less stringent versions of the Energy Code or they predate standards entirely, they offer significant opportunities for cost-effective energy efficiency upgrades. It is crucial that the savings potential and benefits of upgrades be communicated to the end user to stimulate retrofits.

The Research: This project compared baseline energy use in homes to the energy use after envelope and HVAC efficiency retrofits. The researchers leased four homes of different vintages (1948, 1953, 1996, and 2006) in Stockton, California, and heavily instrumented them to collect data on a set of carefully designed and controlled experiments in energy efficiency retrofit measures. The instruments controlled the operation of the HVAC systems, monitored and provided system efficiency performance data, and simulated occupancy using humidifiers and heaters for simulated latent and sensible heat gain (Figure 4).

Figure 4: Equipment Used to Simulate Occupants in Research Homes

Left: The control system for operating and recording the HVAC, humidifiers, heater fans, and other systems to simulate occupancy.

Middle and Right: The humidifiers and heaters used to simulate latent and sensible heat gain from typical occupancy.

Source: Bruce Wilcox, P.E.

First, this project analyzed the heating and cooling loads and efficiency of the homes using the original HVAC systems, and it compared this data to a reference HVAC system used as a baseline (Figure 5). In addition to gathering baseline data, the researchers produced a calibrated simulation model of the energy use in each home, using the measured characteristics and detailed hourly data to adjust model parameters and algorithms for accuracy. Finally, the measured energy use of the homes was compared to the simulated energy use of a similar, new home that meets current Building Energy Efficiency Standards.

Next, a method to measure energy use and efficiency in homes was established which retrofitted the test homes with different packages of building envelope and HVAC efficiency upgrades. These packages included installing efficient ducts, advanced HVAC systems, insulation, air sealing, modern windows, and remotely operable whole house fans. The goal was for the homes to achieve 50 to 75 percent savings in heating and cooling energy by using

cost-effective retrofit techniques, which could be applied as part of a multi-house optimized upgrade program.

Figure 5: Reference Cooling System Installed in the Research Home

The reference cooling and heating systems, which provided baseline data on heating and cooling loads and efficiency of the homes, were located indoors (except for the condensing unit) to negate the effect of duct conduction or leakage resulting from the system being outside the conditioned space.

Source: Bruce Wilcox, P.E.

Some of the research findings included improved efficiency potential from ducts and whole house fans. Specifically, this project showed that ducts do not need to be located in the conditioned space to achieve high efficiencies. Moreover, reducing duct restrictions and the size of the HVAC units in all four homes allowed the cooling coil airflow to increase from an average of 297 to 534 cubic feet per minute per ton of cooling.[21] This combination of increased duct efficiency, increased cooling air flow, and increased compressor efficiency provided significantly higher post-retrofit cooling efficiencies in all four homes. In addition, the project showed cooling energy consumption reductions from the installation of whole house fans. When these reductions were added to insulation, strategic air sealing, and high efficiency windows, the cooling loads were reduced by over 70 percent in the homes with poor insulation and by 45 percent in a home with 1996 insulation levels.

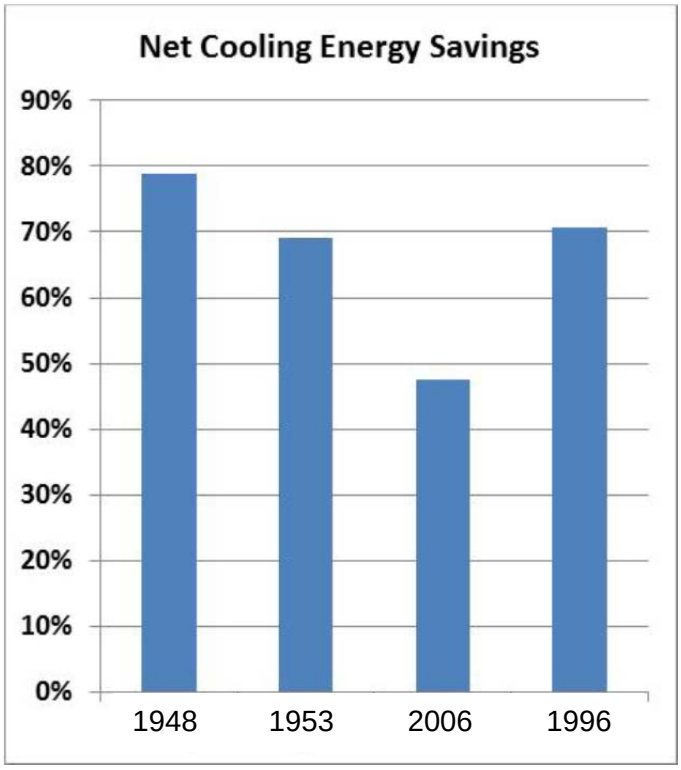
*Envelope and HVAC efficiency upgrades saved an average of **73 percent** of the cooling energy in the three oldest test homes, and **48 percent** in the newest test home.*

This project is continuing to test improvements to the heating and cooling energy estimates produced by the Energy Commission's Home Energy Rating System software and procedures. Potential areas of improvement include better identification and characterization of alternative air distribution systems that are widely used and that impact energy use.

21 One ton of cooling is equivalent to 12,000 BTUs per hour of cooling or approximately 3.5 kW of cooling.

The Benefits: The project developed envelope and HVAC efficiency upgrades that saved an average of 73 percent of the cooling energy in the three oldest test homes, and 48 percent in the newest test home (Figure 6). The upgrades were completed with simple, common retrofits such as efficient ducts, advanced HVAC systems, insulation, air sealing, whole house fans, and low-emissivity glass windows. Additionally, this project has provided vital information to aid in the development of new Title 24 Building Energy Efficiency Standards that will further reduce energy consumption in new and existing buildings. Notably, it has proved ground-breaking technologies that reduce both annual energy consumption and peak energy usage, offering high potential energy savings for California homes. Finally, some of the measures proven in this project could be used in direct install programs. Such programs could bring a larger number of homes in line with California's energy and emission reduction goals.

Figure 6: Net Cooling Energy Savings



The net cooling energy savings of all four test homes after retrofits.

Source: Bruce Wilcox, P.E.

Agreement Number: 500-10-014 Contractor: Bruce Wilcox, P.E.
Project Cost: $1,822,091 Co-funding: $880,000 Project Term: September 27, 2010 to March 15, 2015

The Project: Saving Energy and Time by Sealing Leaks with an Aerosol Mist: A Novel Approach to Improving Building Efficiency

The Issue: Building shells are notorious for leaking, causing unintended air flows between conditioned and unconditioned spaces that result in additional loads that the HVAC equipment must remove. A significant effort has been made to reduce the leaks in building shells through current construction practices, but the problems of high labor costs and quality control remain. Recently, a process was developed that uses aerosolized sealant material to seal leaks in buildings with the goal of achieving better ventilation control and lower infiltration loads. The process involves pressurizing a building interior and releasing a mist of aerosolized particles that move toward and stick to locations where air is escaping, adhering to the edges and building up until the leaks are sealed. However, more detailed data on the technical and economic feasibility of this process needs to be collected through additional demonstrations in residential buildings.

Figure 7: Photos of Aerosol Sealing Installation on Single-Family Home, Including Examples of Seals Formed

Sealed leak in between manual caulk application at the Honda Smart Home

Large sealed leak on a ceiling beam at the Honda Smart Home

The red circles highlight the infiltration points of the aerosol sealants that conventional manual sealing missed.

Source: Western Cooling Efficiency Center

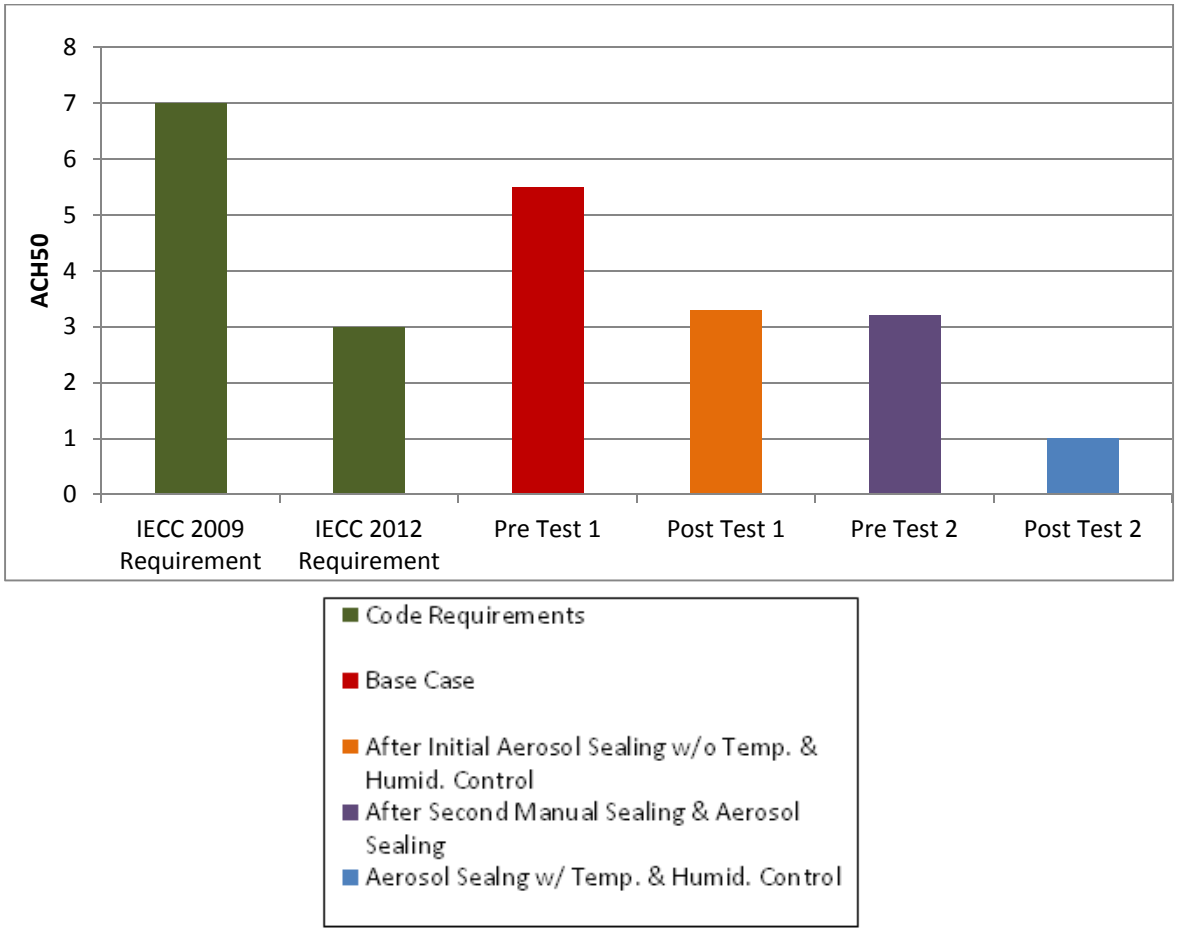
The Research: Previous research conducted in 2013 focused on developing a prototype aerosol sealant deployment system. In 2014, the Western Cooling Efficiency Center (WCEC) at UC Davis began demonstrating the capabilities of the initial deployment system, which included identifying ways to improve the effectiveness of the process and reduce the amount of sealant and time required for sealant application.

A demonstration of the aerosol envelope sealing process was conducted in Davis on the Honda Smart Home, a two-story, single-family, ZNE home built to showcase some of the most advanced strategies to reduce the carbon footprint of homes. The WCEC worked with Honda Motor Company to demonstrate the aerosol envelope sealing process, with the ultimate goal of meeting the very aggressive Passive House air leakage standard of 0.6 ACH50 (Air Changes per

Hour under 50 Pascals of pressure). The building was initially sealed using a standard manual application of expanding foam and caulk, which resulted in a leakage rate of 5.5 ACH50. After applying the aerosol seal, the building air leakage was reduced from 5.5 ACH50 to 1.0 ACH50. This was achieved in two steps, as described below.

The first sealing demonstration used an airless nozzle injection system with five injection points and no temperature or humidity control. This reduced the building leakage from 5.5 ACH50 to 3.3 ACH50 ("Post Test 1", Figure 8). After the first demonstration, three contractors spent 24 hours attempting to further seal the building with expanding foam and caulk, resulting in an almost negligible impact on the overall tightness of the building shell ("Pre Test 2"). Finally, the WCEC applied the aerosol envelope sealing process a second time. In this application, WCEC controlled the temperature and humidity and used air-atomization (instead of airless nozzles), which resulted in further reduction of the building leakage from 3.2 ACH50 to 1.0 ACH50 ("Post Test 2").

Figure 8: Summary of Results of Aerosol Envelope Sealing Demonstration in Honda Smart Home



The effectiveness of aerosol sealing ("Post Test 1" and "Post Test 2") when compared to conventional manual sealing ("Post Test 1" versus "Pre Test 2"). International Energy Conservation Code infiltration requirements are provided for comparison.

Source: Western Cooling Efficiency Center

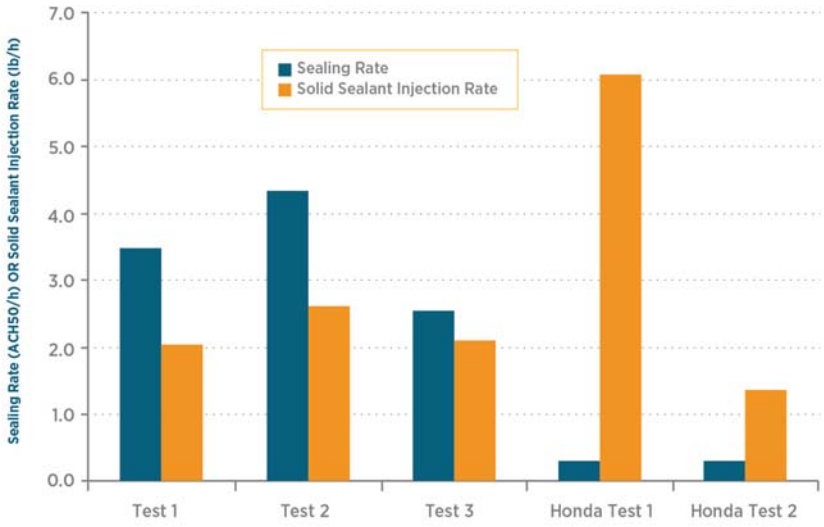
This demonstration illustrated the superior performance of air-atomization nozzles when combined with humidity control on minimizing building leakage**.** Humidity control promoted appropriate evaporation of water surrounding the sealant, which is critical for particles to adhere to leak sites. The first injection ("Post Test 1") used substantially more sealant (about five times more) than the second injection ("Post Test 2") to seal a similar amount of leakage, highlighting that the control process (and perhaps the nozzle type) also saves material cost on the aerosol sealant.

In addition to differences in control and type of atomization nozzle, the two aerosol sealing tests also differed in the number of injector nozzles. The first test used five injector nozzles; the second air-atomization test, only used one injector nozzle. In subsequent demonstrations, the air-atomization system performance improved significantly when multiple injection points (nozzles) were combined with humidity control.

When combined with humidity control, air-atomization nozzles minimize building leakage.

Figure 9 shows a recent sealing demonstration of three apartments using the latest air-based nozzles (four nozzles per apartment) compared to the Honda Smart Home, which used five airless nozzles for "Honda Test 1" and one air-based nozzle for "Honda Test 2." The apartment results show that with the new air-based nozzles and humidity control, a much higher sealing rate can be achieved, resulting in less sealing time while using less sealant than the older process (Figure 10).

Figure 9: Sealing Rates and Solid Sealant Injection Rate of the Three Apartments Compared to the Honda House



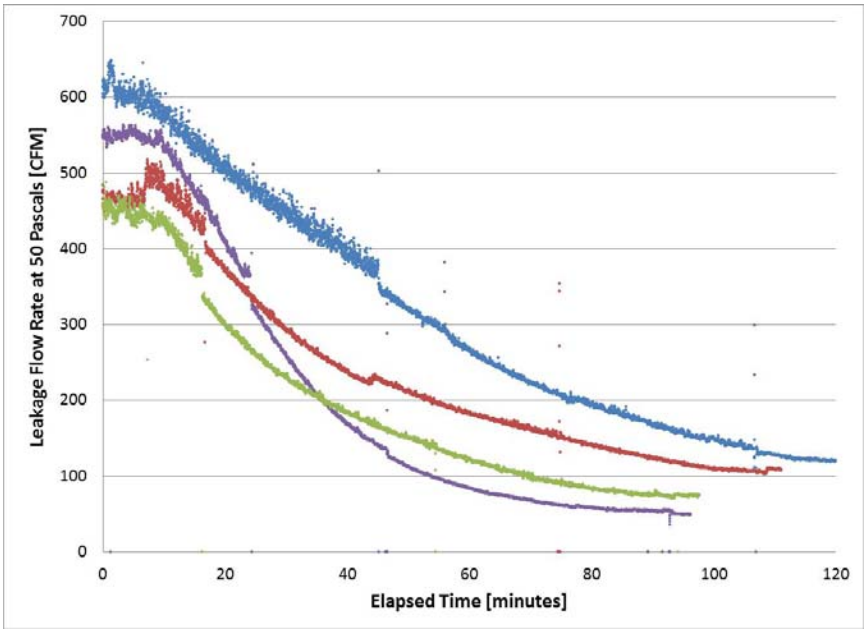
The apartment results show higher sealing rates and lower solid sealant injection rates compared to the Honda tests. The new air-based nozzles and humidity control used in apartments provide a much higher sealing rate and require less sealant than the earlier process.

Source: Western Cooling Efficiency Center

The Benefits: This demonstration revealed the advantages of using the aerosol envelope sealing processes over standard manual sealing methods. The benefits include reduced time and labor, increased effectiveness, and improved air tightness. The research also found that air-atomization nozzle systems with multiple injection points combined with humidity control produces much faster sealing while using less sealant.

If the installation process can be streamlined to the point where any contractor can deploy it, the overall cost of sealing should be equivalent to or less than typical contractor rates for manual sealing while providing better tightness and automated leakage verification. The feasibility of commercialization to streamline this technology for speed and ease of deployment will be tested in late 2014, and WCEC will train contractors to use this technology in the hopes of refining the user experience and further increasing the speed of deployment.

Figure 10: Real-Time Leakage Tracking for Four Apartments



For the four apartments, over 80 percent of the available leaks were sealed in less than two hours. Previous aerosol sealant demonstrations required four hours to reach similar tightness levels.

Source: Western Cooling Efficiency Center

Agreement Number: 500-08-042 Contractor: Western Cooling Efficiency Center
Project Cost: $300,000 Co-funding: $57,000 Project Term: July 1, 2012, to March 13, 2015

The Project: Installing Radiant Heating and Cooling in Near Zero-Net-Energy Buildings

The Issue: Installation of highly efficient radiant heating and cooling systems in buildings has increased in recent years, particularly in ZNE and other advanced low-energy applications. Radiant slab systems cool and heat buildings by circulating water in plastic tubing embedded in the floor or ceiling. Even though the number of installations of these systems is growing, substantially more information is needed on how to design, size, and operate them effectively so that their benefits are fully realized.

The Research: The Center for the Built Environment (CBE) developed information, guidance, and tools for designing and operating radiant heating and cooling systems in near-ZNE buildings. This project included case studies on two buildings, in Sacramento and Berkeley, as well as supporting laboratory and simulation studies to better understand current applications of these systems and explore potential improvements in their design and operation. Both case study buildings featured radiant slab ceilings for cooling and heating combined with a dedicated outside air system in all major office areas of the buildings. The case studies documented the real-world experiences and lessons learned from designing, installing, and operating radiant slab systems in low-energy buildings.

Since January 2014, CBE measured and collected live data from the first case study at SMUD's East Campus Operations Center. The data included measurements recorded by 50 wireless sensors that monitor room air and radiant temperatures, surface temperatures on the radiant ceiling slab, and room air stratification. Additionally, this project collected and analyzed trend data from the building management system. This information allows for review of the control and operation of the radiant slab system and identification of any operational problems, thus ensuring optimal performance of radiant systems.

In addition to collecting measured data, CBE collaborated with the mechanical system designer and SMUD facility staff to use research findings to correct and improve the radiant system control strategies, thus reducing energy consumption. CBE researchers identified two main issues. First, the perimeter zone thermostats located in the exterior wall were reading several degrees lower during nights and weekends when the air handlers were turned off. This caused the radiant slab in those zones to go into heating mode more often than necessary. Building operations staff sealed and insulated the perimeter thermostats which significantly improved the situation. Second, heating and cooling setpoints for the radiant slab system were originally set at values that were more representative of how an air system would be controlled. Working with operations staff, CBE recommended a new setpoint schedule that used setbacks for nights and weekends, thereby allowing radiant slabs to be turned off during unoccupied periods, resulting in energy savings.

Figure 11: Case Study Site 1 – SMUD East Campus Operations Center, Sacramento

Source: Sacramento Municipal Utilities District

The second case study was at the David Brower Center in Berkeley, where an occupant survey was conducted in June 2014. The purpose was to assess the occupants' perception of the indoor environment provided by the radiant slab heating and cooling system and other innovative heating, ventilation, and air conditioning design features of the building. Compared to the first survey conducted in 2010, the 2014 survey results showed improved satisfaction in all major indoor environmental quality categories, including thermal comfort, air quality, lighting, acoustic quality, and overall satisfaction with the building. Figure 13 shows this comparison along with a comparison to the CBE survey benchmark database, containing nearly 53,000 individual survey results.

Figure 12: Case Study Site 2 – David Brower Center, Berkeley

Source: Center for the Built Environment

Detailed field measurements took place from September through October 2014, using the CBE wireless toolkit to measure the indoor thermal environment and the performance of the radiant ceiling slab system. An energy simulation model of the Brower Center was developed to evaluate how effectively the low-building design with radiant slab heating and cooling system performed in different California climates.

In addition to collecting performance data and occupant survey results through field studies, CBE developed an improved understanding of optimized design methods and control strategies for radiant slab systems through a series of laboratory experiments. Laboratory testing in a Hydronic Systems Test Chamber compared the heat removal rate for a radiant chilled ceiling to a standard overhead air distribution system. The findings showed that radiant systems behave differently than all-air systems and should not be modeled using standard techniques designed for all-air systems. The main reason for this observed difference is that an actively chilled radiant surface instantaneously removes radiant heat from external (like solar) and/or internal heat sources as well as interior surfaces within its line-of-sight view. This changes the heat transfer dynamics in a zone of a building.[22,23] This improved understanding allowed for development of more accurate tools and models, which facilitated building design and operational strategies that properly account for these differences.

The Benefits: Highly efficient radiant heating and cooling systems can potentially reduce energy consumption in buildings and contribute to achieving the state's ZNE goals. The CPUC's Energy Efficiency Strategic Plan and the California Integrated Energy Policy Report[24] require that all new commercial buildings be ZNE by 2030. A status report on 160 ZNE commercial buildings in North America indicates a trend toward increasing adoption of radiant systems and away from forced-air HVAC systems.[25] Recent studies show that energy savings from radiant systems can be 34 to 67 percent over conventional systems—far greater than even best-practice all-air systems. A recent article by Sastry and Rumsey reported on a large side-by-side comparison between an optimized forced air system and a radiant slab system with a dedicated outside air system, for a 250,000 square foot building, located in a hot and humid area. The results showed that after two years of operation, the radiant system used 34 percent less energy compared to the optimized forced air system.[26] Other studies, such as those at the Pacific

*Radiant system used **34 percent** less energy compared to the optimized forced air system.*

22 Bauman, F., J. Feng, and S. Schiavon. 2013. Cooling load calculations for radiant systems: Are they the same as traditional methods? *ASHRAE Journal* 55(12), pp. 20-27, December. http://escholarship.org/uc/item/6px642bj.

23 Feng, J., F. Bauman, and S. Schiavon. 2014. Experimental comparison of zone cooling load between radiant and air systems. *Energy and Buildings*, Volume 84, December, pp. 152-159. http://dx.doi.org/10.1016/j.enbuild.2014.07.080.

24 "CA Energy Efficiency Strategic Plan: January 2011 Update." 2011. California Public Utilities Commission. 2011. http://www.energy.ca.gov/ab758/documents/CAEnergyEfficiencyStrategicPlan_Jan2011.pdf.;

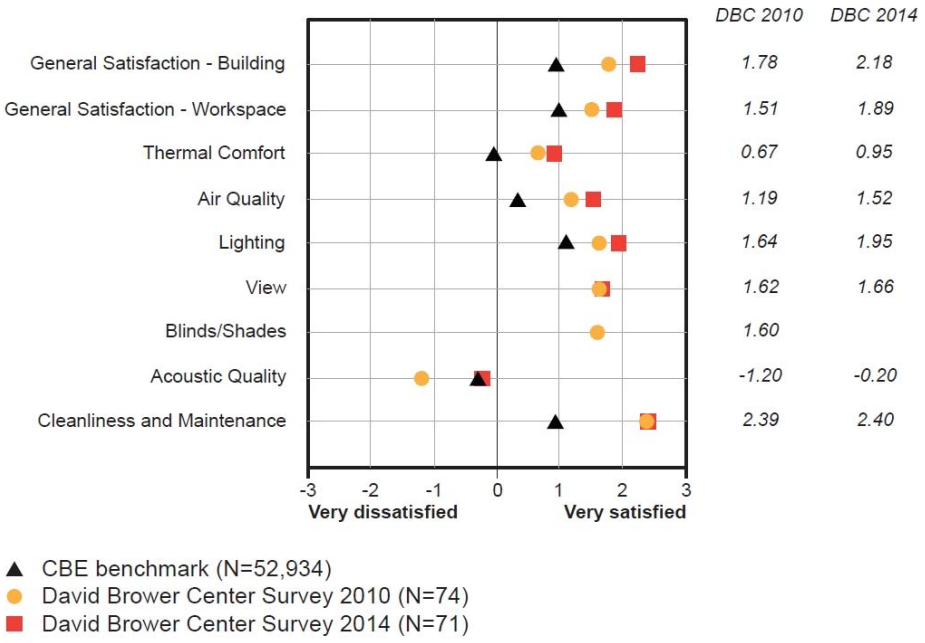
25 "Getting to Zero 2014 Status Update." 2014. New Buildings Institute. http://newbuildings.org/2014-zne-update.

26 Sastry, G., and P. Rumsey. 2014. VAV vs. radiant. *ASHRAE Journal.* 56 (5): 16-24.

Northwest National Laboratory and the National Renewable Energy Laboratory, identified hydronic radiant systems with a dedicated outside air system as one of the leading energy saving strategies. This combination was predicted to achieve 56.1 percent energy savings (national weighted average) for 16 different climate settings, with an average payback of 7.6 years.[27, 28]

The results from the CBE research project inform builders and designers on how to design, size, and operate radiant systems effectively, resulting in more comfortable, energy efficient, and cost-effective buildings in California.

Figure 13: Comparison of David Brower Center Survey Results (2014, 2010) With CBE Benchmark Database



David Brower Center Survey 2010 and David Brower Center Survey 2014 represent average satisfaction ratings (from graph) for surveys conducted in 2010 and 2014, respectively.

Source: Center for the Built Environment

Agreement Number: 500-08-044 Contractor: The Regents of the University of California, Berkeley

Project Cost: $300,000 Co-funding: $0[29] Project Term: September 21, 2012 to March 31, 2015

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27 Thornton, B. A., W. Wang, M. D. Lane, M. I. Rosenberg and B. Liu. 2009. Technical support document: 50% energy savings design technology packages for medium office buildings. Pacific Northwest National Laboratory, Richland, WA.

28 Leach, M., C. Lobato, A. Hirsch, S. Pless and P. Torcellini. 2010. Technical support document: Strategies for 50% energy savings in large office buildings. NREL, Golden, CO.

29 In-kind support (not claimed as match funding) from Price for laboratory testing in Winnipeg for $22,500.

Industrial, Agriculture, and Water End-Use Efficiency Research

The industrial, agriculture, and water sectors in California use 30 percent of all electricity consumed annually in the state.[30] These sectors are vital to California's economy and rely on an affordable, reliable, and sustained energy supply. Through RD&D, the Energy Commission seeks to improve the energy efficiency of industrial processes, agricultural operations, and water and wastewater treatment plants. These sectors are also sensitive to the reliability and quality of electric power. Therefore, in addition to improving energy efficiency, the program also researches, develops, and demonstrates technologies that help these sectors deal with power quality, supply, and reliability issues while improving energy efficiency. The major industries include food processing, cement, electronics, e-commerce, petroleum extraction, refining, and production. The sector also benefits from complementary natural gas-funded efforts to develop and demonstrate technologies that enable renewable resource-fueled processes to be substituted for natural gas-consuming processes.[31]

Examples of recent targeted technology areas include:

- Industrial energy efficiency. Waste heat recovery, energy-efficient industrial heating, cooling or refrigeration, advanced sensors and controls, advanced burners, innovative combined heat and power (CHP) technologies, industrial process heating or cooling from renewable resources, and demand response.
- Water and wastewater. Energy and water use optimization for water and wastewater treatment, reduction in industrial wastewater, water recycling or recovery of processed wastewater, agricultural or landscape irrigation system efficiency.
- Data centers. Cooling and energy use reduction and demand response, power management, innovative server designs, equipment and network improvements.
- Customer-side electricity storage. Energy storage for peak-load reduction, load management or demand response, integration of renewable generation.

30 2011 Emerging Technology Demonstration Grant Program Solicitation, PON-11-501, revised October 2011.

31 For more information, see: Schrupp, L. 2013. Energy Research and Development Division. 2013. *Natural Gas Research and Development 2013 Annual Report.* California Energy Commission. CEC‐500‐2013‐111.

The Project: Reducing Energy Use in Wastewater Treatment Plants With Filtration Systems

The Issue: Wastewater treatment plants (WWTP) are often the single largest electricity users for special districts. The power demand of California WWTPs is approximately 230 megawatts (MW), with an annual energy consumption of over 2,000 GWh, resulting in annual energy costs of $220 million.[32] Current wastewater treatment technology is a step-by-step process that includes primary treatment (initial clarification), secondary treatment (aeration and clarification), sludge thickening (thickening of the untreated residue generated during wastewater treatment), and anaerobic digestion.

The most energy-intensive step is aeration, which accelerates the biological breakdown of organic matter in the wastewater. Reducing the electrical energy requirement of this step has the potential to significantly decrease the overall energy use of WWTPs as well as increase digester gas production. One method of reducing the energy intensity of the aeration process is to pre-filter the wastewater, perhaps by using a primary effluent filtration (PEF) system, a technology that has not yet been implemented at most WWTPs. Typically, filtration systems are used in the tertiary step of the wastewater treatment process. However, no data has been collected on the operation and maintenance costs or the technical and economic feasibility of full implementation of filtration systems prior to aeration.

The Research: The PEF system reduces the organic content of wastewater which reduces aeration power requirements and increases treatment capacity. It also increases the recovery of energy through increased anaerobic digester gas energy production.

The researchers installed five different wastewater filtration technologies at the Linda County Water District's WWTP in Olivehurst, California (Figure 14), placing the demonstration test filters between the primary clarifiers and the secondary treatment process (Figure 15). This configuration allows the PEF system to filter the organic load within the primary clarifier effluent and send the filtered wastewater to the secondary aerated biological treatment system. The reduction of the organic load from filtered wastewater reduces the time required for aeration in the biological treatment phase of the secondary process, resulting in significant energy savings compared to the standard configuration. At the end of the filtration cycle, the filters undergo a cleaning process using either filtered water or primary effluent (depending on the filter technology). The resulting backwash reject water containing the solids captured from the primary clarifier effluent is run through the WWTPs thickening process and diverted to the anaerobic digester, increasing digester gas production. Aeration process energy use and digester gas production are monitored to assess the ongoing performance of the systems.

32 Benedek, Andrew and Juan Josse. 2011. "Opportunities for Energy Reduction in California Wastewater Plants." California Water Environment Association Conference Presentation.

Figure 14: Primary Effluent Filtration Demonstration System Located at the Linda County Wastewater Treatment Plant in Olivehurst

The demonstration site at the Linda County WWTP with all five filters in operation.
Source: Kennedy/Jenks Consultants, Inc.

The Benefits: This modified wastewater treatment configuration demonstrated that PEF for organic content reduction is commercially attractive for achieving significant energy and capital cost savings at WWTPs. First, reducing the primary clarifier effluent organic load (typically measured as biological oxygen demand) will decrease the aeration energy requirement in secondary biological treatment. Second, the high energy content of the captured volatile suspended solids in the backwash reject water will increase the anaerobic digester gas energy production. Last, by reducing the primary effluent organic load, existing secondary biological treatment capacity will either or the required size of replacement biological treatment units will decrease.

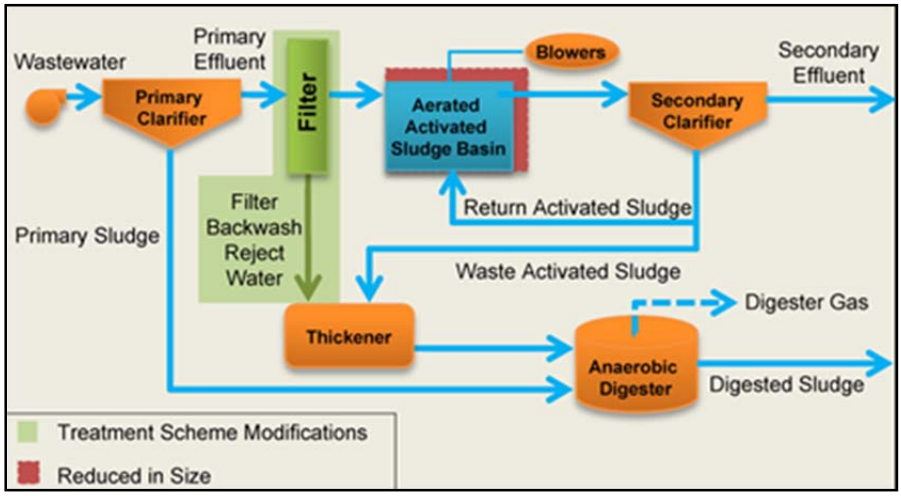
Based on 18 months of demonstration, the results obtained at the Linda County WWTP show overall organic load removal efficiencies of 20 to 45 percent, with more typical rates of 25 to 30 percent. This improvement reduced aeration electrical power requirements by 20 to 30 percent.[33] In addition, the secondary biological treatment capacity increased by 20 to 30 percent. The increased flow of organic solids directed to the anaerobic digester resulted in a 20 to 25 percent increase in biogas production. The magnitude of this increase can vary with the operational conditions of the digester and wastewater characteristics. For 25 percent assumed implementation of the technology in California, it is estimated that the annual energy cost savings would be approximately $29,000,000 per year (using $0.11/kWh as state-wide average).

Based on the results of the project, the researchers estimate that the additional cost of the PEF system would be recovered in less than 10 years, making PEFs commercially attractive for achieving significant energy and capital cost savings. More detailed economic evaluation studies and energy calculations are being undertaken to predict the specific payback periods for

33 These results are in comparison to conventional wastewater treatment systems without PEF, and results will also vary depending on specific WWTP conditions, such as the efficiency of the existing aeration system and performance of the primary clarification system.

different types of WWTPs. The economic evaluations, specific payback periods and energy calculations will be included as part of the final project report in mid-2015.

Figure 15: Modified Wastewater Treatment Flow Diagram



The process flow diagram of a typical WWTP shows where the primary effluent filters have been inserted into the process for carbon diversion.

Source: Kennedy/Jenks Consultants, Inc.

Agreement Number: PIR-11-018 Contractor: Kennedy/Jenks Consultants, Inc.
Project Cost: $1,418,800 Co-funding: $568,800 Project Term: June 29, 2012 to March 31, 2015

Energy Generation Research

Renewable Energy Research

One of the building blocks that will be required to construct California's energy future is the increased use of renewable sources of energy. State-level policies require California to bolster its renewable energy portfolio. The Renewable Energy Research Program targets key technological, performance, and integration barriers of renewable resources such as biomass, solar, wind, and geothermal energy.

The Project: Forecasting Technologies to Boost Solar Energy Production in the Golden State

The Issue: California is the national leader in installed solar photovoltaic (PV) capacity, and installations are growing at a rapid pace to meet the goals of the RPS, California Solar Initiative, Assembly Bill 32, and Governor Brown's Clean Energy Jobs Plan. Solar irradiance, the measure of how much solar power falls on a given surface area, exhibits substantial variability on time scales of days, hours, and even minutes as a result of changes in atmospheric conditions. This variability is reflected in the power output of grid-connected solar photovoltaic systems. Integrating this increasing amount of solar power into the electric grid requires accurate prediction of solar energy generation on a wide range of look-ahead time scales to cost effectively manage the impact of resource variability. This issue is particularly important for large centralized PV installations, where cloud shading and aerosol impacts can have an amplified effect and capacity can drop off rapidly during large ramp events.

The Research: This project assembled and evaluated a composite solar forecast system that integrated four different forecasting methods—sky imagers, satellite, and two variants of numerical weather prediction models—to achieve the best forecast performance for each look-ahead period, ranging from 10 minutes to 48 hours. The researchers developed and used advanced modeling and statistical forecast evaluation methods to quantify and improve the accuracy of generated forecasts.

The forecast target was a 48 MW utility-scale PV power plant which, at the time the project was developed, was one of the largest PV plants in the United States. The plant interconnects to the California Independent System Operator grid using an innovative "pseudo-tie," which allows PG&E to treat the power generated from the Copper Mountain facility as in-state, Renewables Portfolio Standards (RPS)-eligible generation.[34]

Solar forecasting has traditionally been a complex issue due to its dependence on the variable nature of weather patterns. The results of this project are an important first step toward developing an optimally integrated forecasting system that can produce a more accurate forecast, for all look-ahead time frames of interest.

The Benefits: Grid integration studies have assessed the impact of integrating variable energy sources such as wind and solar energy into specific grid systems. A recent study by the National

34 "Pseudo-tie pilot sends more renewable power to California." 2010. California ISO. www.caiso.com/Documents/Pseudo-TiePilotSendsMoreRenewablePower-California.pdf.

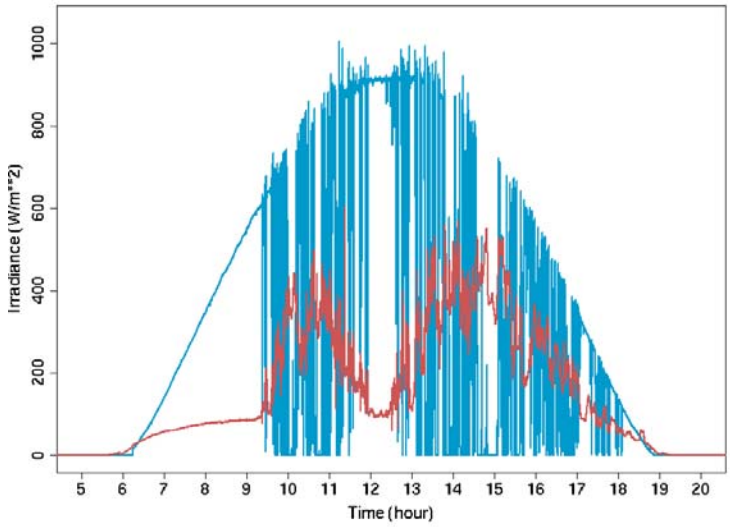
Renewable Energy Laboratory indicated that a 10 percent reduction in the mean absolute error of wind power production forecasts would result in an annual reduction in grid integration costs of $28 million for the Western Interconnection at a penetration level of 14 percent, and an annual reduction of $52 million at a penetration level of 24 percent.[35] While this calculation was based on wind integration, similar reductions in the error of solar forecasts can be expected to yield a comparable magnitude of integration cost reductions.

The advanced analytical techniques used in this project along with the results derived from it will be used to improve the performance of the operational hour-ahead and day-ahead solar power generation forecasts that AWS Truepower provides to California ISO. In fact, many of the project's methods are already being utilized in the California ISO's ensemble forecast system.

In addition to improving overall forecast performance, this research will further refine the component methods already used in the California ISO forecast production with a focus on an improved statistical method to correct system errors in the generated model forecasts. The research presents an optimal way to create a composite forecast from individual ensemble members and provides a foundation for further research on extracting optimal forecast value from both of these approaches. Future opportunities include developing advanced evaluation metrics to account for the time-dependent economic value of generated forecasts and continuing to develop advanced models that account for cloud height, cloud type, the dynamic nature of aerosols, and the impacts that each of these have on PV generation

35 Lew, D., M. Milligan, G. Jordan and R. Piwko. 2011. The Value of Wind Power Forecasting. *Proc. 91st American Meteorological Society Annual Meeting, the Second Conference on Weather, Climate and the New Energy Economy. Washington, D.C.*

Figure 16: A Typical Daily Pattern of Direct and Diffuse Horizontal Irradiance



A typical daily pattern of direct and diffuse horizontal irradiance (blue and red lines, respectively). Since PV systems respond almost instantly to changes in irradiance, similar patterns are seen in PV system output.

Source: http://eo.ucar.edu/webweather/cloud3.html

Agreement Number: 500-10-057 Contractor: AWS Truepower, Inc.
Project Cost: $442,136 Co-funding: $145,519 Project Term: August 8, 2011, to March 31, 2014

The Project: Piloting the Integration and Utilization of Renewables to Achieve a Holistic Energy Infrastructure

The Issue: Many California communities have ambitious goals to achieve self-sufficiency in renewable energy at the local level. However, there is still a need for proven technical and economic models and tools that integrate renewable energy into a community's energy infrastructure in an optimum way.

The Research: Integrating renewable technologies presents a major challenge because renewable resources have limitations that can include location, capacity, cost, daily variation, intermittency, and availability. This project examined key challenges to achieving high penetrations of renewables onto California's grid by investigating the effective use of distributed energy resources, including solar, wind, and biomass for electricity, heating, and transportation. The UC Irvine (UCI) campus served as the model community.

Pilot project demonstrations and dynamic models were evaluated on the integration of renewable generation resources, energy management strategies, efficient land-use and building designs, sustainable transportation, and electrical infrastructure to ensure reliable electricity and transportation for the campus as well as future renewable-based secure communities at the lowest possible cost.

Roadmaps were produced that integrate renewable electric with transportation alternatives to provide a major portion of the energy for the campus, thus reducing reliance on traditional fossil fuels for electric generation and oil for transportation. Pilot projects supporting UCI's energy infrastructure include: a campus co-generation plant; a 4.5 million gallon, 53,000 ton-per-hour thermal energy storage tank; 890 kilowatts (kW) of rooftop PVs and 113 kW of dual-axis concentration PVs; 20 plug-in hybrid electric vehicles and 38 battery electric vehicles; and a biogas combined heat and power plant with a 300 kW molten carbonate fuel cell and hydrogen co-production.

A major portion of the PIER funding received was used to develop a comprehensive community microgrid and utility grid planning computer model called HiGRID. Research conducted under this project included:

- Holistic Energy Integration and Management. Researchers developed the Holistic Grid Resource Integration and Deployment (HiGRID) tool to perform dynamic analyses to integrate an array of technologies, including renewable and non-renewable generation, energy efficiency, demand response, energy storage, and electric transportation to assess community and grid requirements in response to a high penetration of renewable power generation.

- Substation and Distribution Circuit Infrastructure. This project developed flexible circuits for interconnection of distributed energy resources on the UCI substation and distribution microgrid. The distribution microgrid enables the interconnection of distributed energy resources and identifies potential distribution circuit challenges, and its design infrastructure allows for increased distributed energy resources.

- Distributed Energy Resource Deployment. Researchers installed a wireless communication system between major equipment and a building distributed energy resource management system to manage the overall load. Dynamic price signals were used to evaluate and dispatch distributed energy resources to support the grid. Similarly, an existing battery electric vehicle charger was modified to minimize the charge cost of the vehicle with the dynamic price signals.

- Renewable Generation Deployment. Researchers installed, demonstrated, and monitored distributed solar PV systems and pilot concentrated solar PV systems. Researchers also deployed a tri-generation fuel cell system for combined heat, power, and hydrogen co-production at the Orange County Sanitation District.

- Land Use Design and Mobility. Land use design, public transportation, and personal transportation alternatives were evaluated and quantified as strategies to reduce energy consumption and GHG emissions from the transportation sector.

- Building Design and Operation. Researchers developed a building modeling software system to provide a flexible platform for modeling the impacts of design, demand response, and renewable system integration in a single package. Researchers also analyzed building loads that can be managed to facilitate renewable energy generation through efficient building designs, technologies, and operations.

- Public Outreach, Education, and Technology Transfer. UCI developed a website to educate the public about the issues and benefits of achieving a renewable-based energy secure community.

The Benefits: This project demonstrated the effective use of distributed energy resources and geographically available resources, including solar, wind, and biomass for electricity, heating, and transportation. The research addressed an existing need to holistically integrate diverse renewables with dispatchable loads, energy storage, electric transportation, building efficiency, and sustainable land use to maximize renewable penetration.

Specifically, the researchers showed that complementary technologies, such as energy storage, fuel cells, demand response, and electric vehicles, aid the system in increasing renewable utilization, and their preferred operation will change with renewable penetration. Additionally, the research noted that avoiding curtailment of renewable generation is critical for reaching renewable energy goals in a cost-effective manner. Before curtailment occurs, the levelized cost of electricity increases linearly in the range of 0.7 percent to 6.5 percent in cost per percent increase in renewable penetration. After curtailment, this rate increases exponentially, reaching as high as 350 percent increase in cost per percent increase in renewable penetration. Finally, all scenarios exhibited an increase in the leveled cost of electricity with increased renewable penetration on a local scale. This highlights the importance of developing and implementing new economic mechanisms, such as dynamic rate structures, that provide incentives to dispatch community resources in support of grid management for high penetration of intermittent renewable resources.

The research results indicate that UCI's holistic energy infrastructure, which consists of electric power generation, electric vehicles, renewable energy utilization, and building load management, has maximized deployment and utilization of renewable energy resources. All this was accomplished while satisfying reliability criteria, enhancing and sustaining power quality, and minimizing the cost of electricity. Utilizing community resources and capabilities to support the grid-wise high penetration of intermittent renewables has not only supported existing policy and helped achieve the statewide renewable utilization goals, but it has also provided a basis for future energy policy. Furthermore, the methodologies developed at UCI are transferable to other communities.

Figure 17: Concentrated Photovoltaic Panel at UC Irvine

One of the two concentrated PV panels on UC Irvine's campus, which generate 60 kW and 53 kW.

Source: California Energy Commission

Agreement Number: PIR-08-033 Contractor: The Regents of the University of California, Irvine
Project Cost: $948,903 Co-funding: $948,903 Project Term: July 29, 2009, to March 31, 2014

Energy-Related Environmental Research

The energy sector has broad implications for the environment, and while California builds its renewable energy portfolio to attain its energy goals, it must also support its legacy of visionary environmental policy goals. The Energy-Related Environmental Research Program develops cost-effective approaches to evaluating and resolving environmental effects of energy production, delivery, and use in California. It also explores how new energy applications and products can solve existing environmental problems. This energy-environment nexus research fills the critical need of informing decision makers and stakeholders on the environmental implications of developing technology by improving regulatory decision-making and shaping policy.

The Project: Minimizing the Effects of Wind Energy Facilities on Birds in California

The Issue: California's Renewables Portfolio Standard mandates the growth of renewable energy to meet energy consumption demands. While the environmental impacts of traditional energy resources—fossil fuel power plants—are well-known, newer sources of clean energy may also pose risks to California's sensitive ecosystems and the wildlife species they support. For instance, wind energy facilities are causing considerable concern in some locations over their impact on migratory bird and bat populations. To mitigate the impact of existing and future energy development on California's rich ecosystems, it is necessary to develop innovative tools that will help assess, avoid, and monitor the risk and impact to wildlife.

The Research: Most avian fatalities occur during migratory periods, which often take place in seasonal pulses, or even at different times of day. This research project examined weather radar data to locate avian migration patterns and helped develop tools that can identify migration corridors. Birds, bats, and insects scatter waves that result in radar noise, which is typically deleted from weather analyses. However, because weather data is gathered in real-time, it can be used to identify signs of ecological activity in the air, fine tune the operational timing of wind farms to avoid or reduce bird fatalities, and identify migration corridors and ecological high-risk areas that can inform facility siting decisions. Predicting under what type of meteorological conditions migration occurs presents another opportunity to decrease the number of avian fatalities.

Researchers developed a low-cost, high-resolution genomic marker technique to distinguish specific bird populations with migration events at or near wind energy facilities. Genomic markers are a DNA sequence with a known pattern that can be used to identify species. More than 180,000 bird feathers from about 50 species have been collected throughout the Americas during different phases of migratory events. Compared to the identification of birds by banding their legs, which is less than one percent successful due to low recapture rates of banded birds, genomic markers provide extensive details on how birds migrate. This revolutionary approach has a nearly 100 percent success rate and it informs as to the geographical ranges of birds as well as provides evidence on migration timing.

Figure 18: Wilson's Warbler

The researchers performed their genomic marker testing on Wilson's warbler, a species with little known in regard to its migration patterns and with a declining habitat range. This type of genomic marking can be applied to endangered species to understand their flight patterns near wind energy facilities.

Source: Stanford University

"These genomic tools provide 'resolution of populations we've never seen before,'" according to Kristen Ruegg, the project's main researcher, as quoted in Science Magazine's latest news report which highlights the ground-breaking project. The article also cites an ecologist at Oregon State University who states that the approach is "'probably the wave of the future for determining geographic connections on a regional scale."[36]

Researchers can collect feathers from birds that have been killed at wind energy sites and analyze the DNA in the tissue at the base of the feather to determine and track which species of birds are most likely to be impacted by collisions with wind turbines.

The Benefits: The combined use of radar data and genomic markers ensures a reliable, cost effective means of attaining information about birds whose migratory paths are near wind turbines. Understanding these patterns can inform wind energy operators who make siting and operational procedure decisions. Mitigation measures can be developed to protect the birds, such as shutting down turbines, during high migration events. On a larger scale, this method has the potential to be applied to species that are endangered or protected by the Endangered Species Act.

In addition, this information can be used by wind production forecasters. If wind turbines are shut down during heavy migration periods, forecasters would need to replace the energy that would have been generated by the turbines with another source.

36 Stokstad, Erik. 2014. "Hidden Bird Migrations Revealed by DNA." Science Magazine. http://news.sciencemag.org/biology/2014/08/hidden-bird-migrations-revealed-dna.

Figure 19: Wind Turbines in Montezuma Hills, Solano County

Source: California Energy Commission

Agreement Number: 500-11-003 Contractor: The Regents of the University of California, Santa Cruz
Project Cost: $149,996 Co-funding: $0 Project Term: June 29, 2012 to March 31, 2015

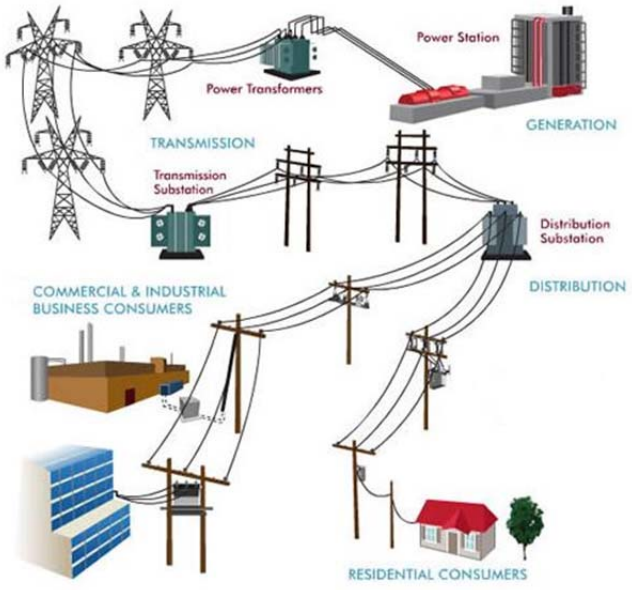
Energy Infrastructure Research

Why Today's Energy Infrastructure Needs Innovation

Since Thomas Edison designed the first electricity station in 1880, maintaining reliable electricity systems has become amazingly complex. The electric grid must now connect generators of all sizes and types and transmit electricity of varying voltage across vast distances to diverse users, from manufacturing plants to mountain cabins. The grid is physically massive and fixed and must accommodate demand that fluctuates constantly. Electricity demand generally peaks on hot summer afternoons, but the grid must have the capacity to meet that level of demand year-round. Peaker plants are used to expand capacity during peak times, but are expensive to build and maintain.

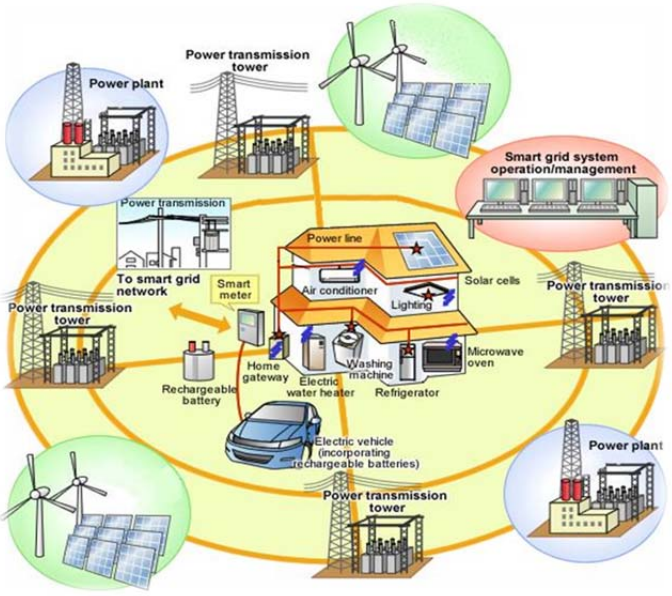
The electric grid was once a simple, one-way, power flow system, with centralized plants that used cheap, abundant fossil fuels to transmit power (Figure 20). Recent advancements in energy efficiency, renewable generation, and other energy areas are dependent on a grid that both receives and generates energy (Figure 21). Examples include rooftop solar panels, photovoltaic systems, and plug-in electric vehicles. Demand response technologies that prompt users to decrease energy use during peak periods make the grid more reliable, but they also require a system that is capable of two-way communication. Renewable sources like solar and wind have variable output, so the grid must now be able to store and use energy on demand, otherwise, low-output periods (such as cloudy, windless days) could cause grid instability or blackouts. A stable, reliable energy future depends upon these and other transformations of the electric grid.

Figure 20: Aging, One-way, Centralized, Carbon-Based Grid With Reliability Issues



Source: VentureBeat

Figure 21: An Advanced, Efficient, Flexible Grid With High Levels of Renewables, Electric Vehicles, and Storage that Provides Reliable Clean Power



Source: Renesas Electronics Corporation

The Energy Commission funds the Energy Infrastructure Program which supports these goals. Research done by the Program analyzes a wide spectrum of priorities and challenges; focuses on demonstrating key products and elements of the infrastructure; and examines the cost-effective integration of new and emerging technologies and solutions. The findings of this research combine to help inform decision and policy makers that will build a smart energy infrastructure that is able to power California's future.

The Project: Deploying Renewables and Modernizing the Grid With the EcoCampus

The Issue: Integrating renewable energy is challenging for legacy systems and utilities and customers need new technology that is capable of distributing energy reliably, efficiently, and cost-effectively.

The Research: ARRA and PIER funds helped California utilities fund the upgrade of their electrical systems to accommodate greater use of renewables. For example, Burbank Water and Power (BWP) were awarded ARRA and PIER funds to upgrade an aging operations facility, integrate PV, and modernize their electrical system. This smart grid equipment can now accommodate renewable generation which helped BWP improve customer service, promote energy efficiency and demand response, and improve overall operations.

The BWP EcoCampus, which is a renovated electric utility operations center in Burbank, California, acts as a showcase for energy efficiency, demand response, and smart grid activities. With a solar array of 1,074 panels that produce 352,000 kWh annually, the EcoCampus demonstrates how customers can integrate PV technology. It also highlights recent advancements in concentration solar cells, tracking systems, and inverters that facilitate the smart grid integration of on-site solar energy resources with the larger electric power system. Three EcoCampus buildings are LEED Platinum certified due to their innovative landscape irrigation system that is supplied solely with recycled water.

"I could see during my very first tour of Burbank Water and Power's EcoCampus, the thoughtful innovation incorporated into their modernization," said California Senator Carol Liu. "The EcoCampus is an evolving model of what can be accomplished when we work together to protect the environment, conserve our precious resources, and promote sustainable practices."[37]

Additional system-wide ARRA and PIER funded improvements include installing smart meters, upgrading utility communications, implementing distribution automation, designing new electrical rate programs, and installing electric vehicle charging stations.

37 "Burbank Water and Power Attains Third Platinum LEED Certified Building on its EcoCampus." Burbank Water and Power. 2014.
http://burbankwaterandpower.com/component/content/featured?start=5.

Figure 22: Completed Solar Carport, Courtyard, and Campus Entrance

Solar panels are located on the EcoCampus entrance and carport, and the water drainage systems capture and utilize water for the campus' landscaping needs.

Source: Burbank Water and Power

The Benefits: The EcoCampus serves as a showcase on incorporating distributed solar generation. In recognition of its efforts, BWP won the 2014 Green California Leadership Award in the Green Building category, which highlights outstanding environmental achievements in California government that are publicly financed and executed and provide a measurable benefit to the natural or human environment. This project is a successful example of integrating distributed renewables with the smart grid, which will improve reliability and availability. The energy that EcoCampus produces has a value of $53,000 per year and the water that it recycles is extremely valuable as well, given that California is now in its fourth consecutive year of drought. (The City of Burbank now recycles 14 percent of its water annually).

To view a BWP's EcoCampus presentation, see the AHBE Landscape Architects' video, "Building a Sustainable Future,"[38] at the link below.

38 "Building a Sustainable Future." 2012. AHBE Landscape Architects. http://vimeo.com/34909303.

Figure 23: Completed Centennial Courtyard

This courtyard was previously a substation with contaminated oil transformers and switches; it is part of a community park.

Source: Burbank Water and Power

Agreement Number: PIR-11-017 Contractor: Burbank Water and Power

Project Cost: $1million Co-funding: $39,735,991, including a $20 million ARRA grant Project Term: May 18, 2009 to March 31, 2013

Energy Storage: A Necessary Link Between Renewables and a Modern Electricity System

California's power grid delivers electricity as it is generated. However, energy from renewable sources like solar and wind is intermittent and can be unpredictable with generation that does not always align with demand. Energy storage fills the gap between the time renewable electricity is generated and the time it is used. Storage can also help grid operators and utilities take full advantage of abundant renewable energy while providing reliable electricity that matches supply with demand.

In California's low-carbon, flexible-grid future, energy storage will be critical during periods of low demand and high production, so that the output power of renewable generation sources can be regulated and integrated into the power grid. This system also eliminates GHG emissions from conventional fossil fuel generators that have been used predominantly for this purpose.

As California advances toward its Renewable Portfolio Standard (RPS) goals, energy storage plays a significant role in successfully integrating renewables into the grid. In 2010, Assembly Bill 2514 (Skinner, Statutes of 2010) was signed into law, recognizing the importance of energy storage in meeting both the RPS and AB 32 goals. In 2013, the CPUC established an energy storage procurement target of 1,325 MW by 2020 for three of California's investor-owned utilities.

All energy storage research projects of which are near completion, including RD&D of batteries (zinc-halogen, sodium-sulfur, iron-chromium, and lithium-ion), flywheels, and compressed air energy storage for bulk energy storage. Each of these energy storage projects is working to overcome challenges in common areas such as cost, operation, permitting, durability, performance validation, safety, and reliability. Furthermore, these projects provide valuable experience and lessons learned that will help move California toward its energy goals.

The Project: Integrating Flow Battery Storage Into the Smart Grid for Renewable Energy Applications

The Issue: Grid-scale, long duration energy storage is crucial as California advances towards high penetrations of renewable resources. Short duration energy storage (about 15 minutes) such as lithium ion batteries and flywheels is used to accommodate quick changes in electrical demand, but such storage is not economical on a large scale. Recent introductions of flow battery technologies are paving the way for grid-scale energy storage, but current costs are too high to permit more than a small number of demonstrations. Additionally, utilities are hesitant to recommend energy storage technologies for consideration by regulatory authorities until the utilities obtain more operational data. Until these battery systems and their economic benefits can be validated and verified, project financing remains difficult.

The Research: This PIER and ARRA funded project is demonstrating a grid-scale iron-chromium redox flow battery (RFB) energy storage system to optimize a 150-kW PV system and a 260-kW irrigation pump. The RFB energy storage system involves chemical reduction and oxidation reactions to store energy in salt-water solutions (such as iron chloride and chromium chloride dissolved in water) that are similar to sea water.[39] EnerVault began developing this technology in 2010, and it is one of the largest RFB energy storage systems in the world.

For this project, EnerVault scaled-up, developed, and is now demonstrating the commercial viability of its RFB energy storage system. The system integrates 250 kW of power and a one megawatt hour of usable energy storage capacity system with a dual-axis tracking 150-kW PV system, which is used to power an irrigation pump on an almond farm located near Turlock, California. This demonstration addresses the need to reduce energy storage costs and improve reliability. EnerVault is collecting and analyzing real-world operational data to validate and verify the RFB energy storage system's performance and is quantifying economic benefits and operating costs. Successful completion of the demonstration is anticipated to lead to wide deployment.

The Benefits: On May 22, 2014, the Energy Commission joined the Department of Energy, the CPUC, and the California ISO to dedicate the EnerVault Turlock project (Figure 24). Speaking at the dedication ceremony, Robert B. Weisenmiller, Chair of the Energy Commission emphatically stated that "the EnerVault Turlock project solidifies California's position as an incubator of companies that attract investment, and demonstrates the value of public-sector investments in energy research and development. This storage technology will help integrate renewable energy and improve the reliability of California's evolving electricity system. Federal and State investments were critical to taking this project from laboratory prototypes to community-scale, energy storage system in less than five years."[40]

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39 "Redox Flow Batteries." 2014. Energy Storage Association. http://energystorage.org/energy-storage/technologies/redox-flow-batteries.

40 "California Energy Commission Joins U.S. Department of Energy to Dedicate EnerVault's Long-Duration Energy Storage System." 2014. California Energy Commission. http://www.energy.ca.gov/releases/2014_releases/2014-05-22_EnerVault.pdf.

Dr. Imre Gyuk, DOE Energy Storage Program Manager, called EnerVault Turlock "the lynchpin to grid stability as we achieve high penetration of renewable energy… the first battery of its class of [DOE ARRA] grantees to reach field commissioning." Assembly member Nancy Skinner, author of Assembly Bill 2514, agreed, congratulating EnerVault Turlock "as an innovative example of long-duration, grid-scale energy storage ready to enter our new energy storage marketplace."[41]

On-going benefits from this project include energy efficiency savings from the storage systems, use of advanced long-duration energy storage for peak load management, and energy storage during non-peak generation periods to maximize existing grid assets. Moreover, this project will demonstrate the viability of RFB systems for long-duration, grid-scale applications that improve grid reliability, facilitate integration of renewable resources, and improve the use of existing transmissions assets.

To view a video of EnerVault Turlock's dedication ceremony, see the highlights[42] or the full speeches[43] at the link below.

41 Ibid.

42 "EnerVault Turlock Dedication Highlights May 22 2014." 2014. EnerVault. https://www.youtube.com/watch?v=k3dcUExtQhc.

43 "EnerVault Turlock Dedication May 22 2014 – Full Video." 2014. EnerVault. https://www.youtube.com/watch?v=I55um8u3GhM

Figure 24: EnerVault Flow Battery Integrated with Photovoltaic System in Turlock

EnerVault Flow Battery Energy Storage System installed at an almond farm outside Turlock.

Source: EnerVault Corporation

Agreement Number: PIR-10-066 Contractor: EnerVault Corporation

Project Cost: $476,428 Co-funding: $9,052,139, which includes a $4,764,284 ARRA grant Project Term: September 9, 2011 To December 31, 2015.

Electric-Related Transportation Research

Transportation has the largest carbon footprint of any economic sector in California and accounts for nearly 40 percent of the state's total energy consumption. With more than 27 million registered vehicles consuming nearly 18 billion gallons of fuel annually, state-level policies have been put in place to support advances in alternative fuels and vehicle technologies to reduce GHG. In March 2012, Governor Jerry Brown issued an executive order directing state government to help accelerate the market of zero-emission vehicles, including electric vehicles, with a goal of 1.5 million in California by 2025.[44]

Electric-related transportation research contributes to California's goals of reducing air pollution and GHG emissions, and provides support to efforts that improve grid services. Research advances technologies that address plug-in electric vehicle needs and grid stability issues by developing advanced grid support capabilities, smart charging, demand response, and energy storage. Innovative methods that successfully integrate plug-in electric vehicles to their energy needs have the potential to provide widespread, cost-effective solutions that will support California's renewable resource power grid.

The Project: Integrating Electric Vehicles Into the Power Grid to Improve Reliability

The Issue: Zero-emission vehicles are a key component of the state's long-term transportation strategy: electric vehicles can reduce GHG emissions, improve the state's air quality by reducing pollution, and potentially save drivers money. However, the increased power demand accompanying electric vehicle adoption can be a serious liability for power systems if not managed carefully. With supporting policies and incentives, electric vehicle load could actually support grid stability and help integrate variable renewable resources. Toward this goal, Governor Brown's executive order envisions advanced charging capabilities for electric vehicles by 2020 The Governor's 2013 Zero-Emission Vehicle Action Plan[45] (ZEV Action Plan) lists specific deliverables and actions to help achieve its goals. One of these deliverables is a strategic roadmap that outlines the paths and priorities for integrating electric vehicles with the power grid.

The Research: In response to the Executive Order and to the ZEV Action Plan, California ISO worked with the Energy Commission and other stakeholders to develop the Vehicle-Grid Integration Roadmap. The Roadmap is a key component of the ZEV Action Plan and the first of the Plan's deliverables to be completed.

The Vehicle-Grid Integration Roadmap outlines the paths and priorities for commercializing the use of electric vehicles to improve power grid reliability. It was a coordinated effort led by California ISO, the CPUC, the California Air Resources Board (ARB), the Energy Commission, and numerous stakeholder groups. The California ISO and the Energy Commission hosted four

44 Governor Brown Zero-Emission Vehicles Executive Order. 2012. http://gov.ca.gov/news.php?id=17463.

45 "2013 ZEV Action Plan: A roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025" 2013. http://opr.ca.gov/docs/Governor's_Office_ZEV_Action_Plan_(02-13).pdf.

workshops to gather stakeholders' feedback on the Roadmap, which DNV GL (technical advisor to the global gas and oil industry) compiled and integrated. Stakeholders identified barriers to the implementation of grid-integrated electric vehicle charging, including:

- Vehicle-Grid Integration Value and Potential;
- Enabling Policies, Regulations, and Business Processes; and
- Enabling Technology Development.

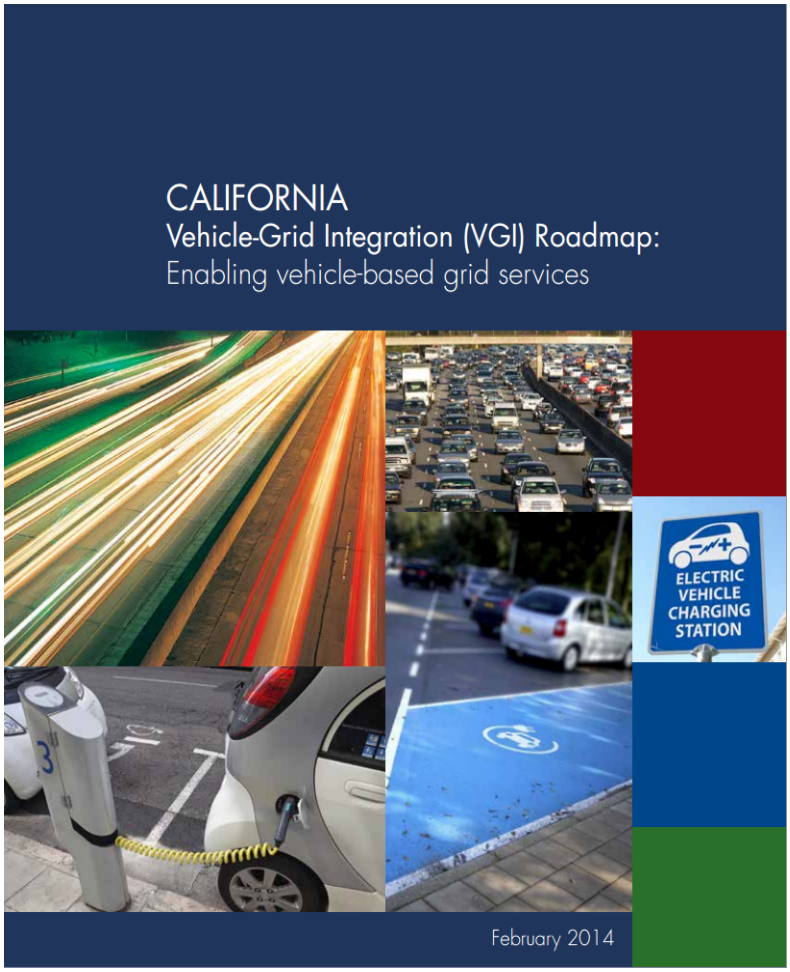
The Benefits: The Roadmap integrates elements of the ZEV Action Plan and establishes objectives for accomplishing the state's goals. It also outlines the ways that electric vehicles can help improve grid reliability, and highlights necessary innovations that integrate the vehicles with grid services while meeting drivers' needs. The Roadmap is helping to shape research objectives and policy considerations across numerous agencies and stakeholder groups. As these groups work together and as the complex interface between vehicles and the electricity grid evolves, the document can be updated and adjusted.

California ISO, the lead agency for the Roadmap, sees the publication as an important tool for coordination across agencies. Heather Sanders, California ISO Director of Regulatory Affairs and manager of the Roadmap's development, stated: "As the electricity system in the state evolves, now is the time to advance coordination with state agencies and stakeholders to realize the untapped benefits from widespread use of electric vehicles."[46] As the lead agency, California ISO is providing valuable input on vehicle-grid integration. The CPUC has developed a framework for developing utility regulations to support vehicle-grid integration and is continuing with outreach to inform its alternative fuel vehicle rulemaking. The Energy Commission has committed to holding annual workshops to review progress on vehicle-grid integration research and demonstration projects, and vehicle-grid integration topics are a major component of its Statewide Plug-In Electric Vehicle Infrastructure Plan.

The VGI Roadmap calls for advancing technologies to support communication, control, two-way power flow, and other capabilities to help lower costs and improve VGI performance. Stakeholders who contributed to the roadmap also identified the limited coordination between manufacturers, grid operators and policymakers as a barrier. Integrated demonstrations may help address these barriers. Demonstrations will be used to prove out technical concepts, to ensure technical standards and specifications are met, and to publicize the potential of VGI-enabling technologies.

46 "California ISO rolls out roadmap to drive benefits of EVs." 2013. http://www.caiso.com/Documents/CaliforniaISORollsOutRoadmap-DriveBenefits-ElectricVehicles.pdf.

Figure 25: Vehicle-Grid Integration Roadmap Cover Page



Source: California Independent System Operator

Agreement Number: KEMA-11-006 Contractor: DNV GL (formerly KEMA)
Project Cost: $109,965 Co-funding: $0 Project Term: July 1, 2013 to February 3, 2014

The Project: Recycling Batteries for California's Plug-In Electric Vehicle Lithium-Ion Battery Packs

The Issue: As California's plug-in electric vehicle market expands, cost-effective and environmentally friendly disposal of lithium-ion battery packs is a major concern that must be addressed. To date, the majority of lithium-ion batteries that need to be recycled/disposed of are smaller cells, such as those used in portable consumer electronics. Currently, there is no established system or standard process designed specifically for disposing or recycling larger and potentially hazardous lithium-ion batteries used in plug-in electric vehicles. Conventional recycling practices, including smelting and hydrothermal digestion, are ineffective and recover only a small portion of the low-value materials found in these batteries. High value materials such as lithium and graphite must be destroyed or burned off, making the recycling process more costly than the value of the materials recovered. Without research to develop advanced recycling processes, the high cost of recycling and disposing of these batteries will increase the upfront cost of the battery packs, which could increase the cost of plug-in electric vehicles.

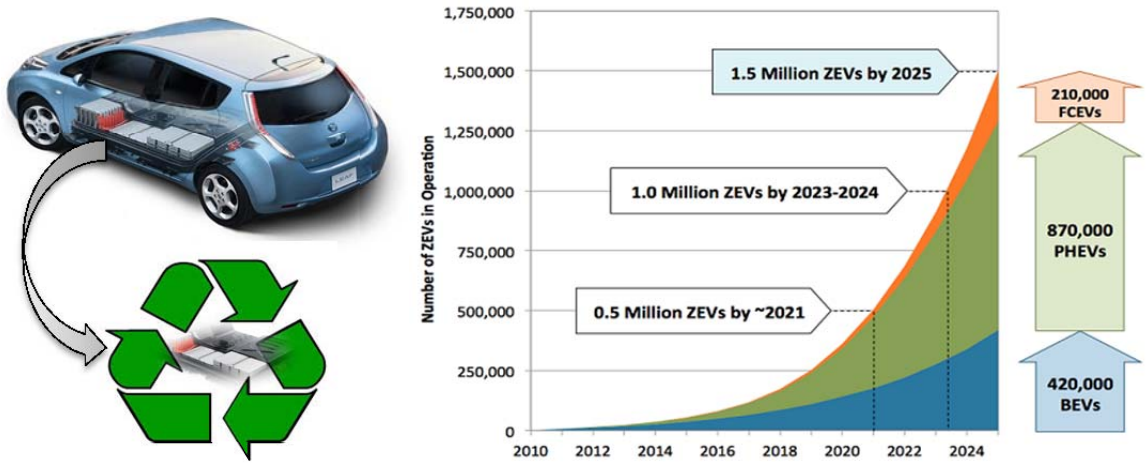
Advanced recycling technologies designed specifically for large lithium-ion batteries are needed to recover valuable materials that can help offset the high up-front costs of these battery systems, avoid increases in the amount of hazardous materials that must be processed and taken to California's landfills, and reduce California's dependence on foreign lithium supplies.

The Research: Farasis Energy, Inc., developed and demonstrated the technical and cost feasibility of an innovative recycling technology known as Direct Recycling, designed specifically for large lithium-ion battery packs. Direct Recycling allows for the full recovery of the high value electrode active materials and conductive additives, including lithium and graphite, which accounts for more than 60 percent of the battery material cost. The recovered materials are separated, purified to remove contaminants, and regenerated to be used in the production of new lithium-ion batteries. Using lithium-ion batteries, researchers collected and processed the recyclable materials through Direct Recycling, and then manufactured pouch cells using the materials for testing and analysis. Data collected from the demonstration was used to develop a cost model for implementing the technology throughout California.

The research demonstrated successful separation and purification of the anode materials and is in the process of separating and purifying the cathode materials. Based on the project results, Farasis Energy, Inc., estimated that the recovery of active materials could reduce battery pack costs by 20 to 40 percent.

The Benefits: Successful development and demonstration of Direct Recycling will accelerate the growth of low cost, self-supporting recycling infrastructure for used lithium-ion battery packs. This advanced recycling process will help create a sustainable market for energy efficient applications of recyclable lithium-ion energy storage systems, which would lead to new material supply streams for lithium-ion battery manufacturers. Battery cell costs could be reduced by a 20 to 40 percent, thereby reducing the cost of plug-in electric vehicle batteries to consumers. As the electric vehicle market grows, successful implementation of Direct Recycling will minimize, and hopefully eliminate, the impact of hazardous materials on California's landfills.

Figure 26: Advanced Battery Recycling Will Enable the Projected Growth of Plug-In Electric Vehicles in California



Electric vehicle batteries can undergo Direct Recycling (L) and graph of projected plug-in electric vehicle growth through 2025 (R).

Source: Marc Melaina and Michael Helwig[47]

Agreement Number: PIR-12-006 Contractor: Farasis Energy, Inc.
Project Cost: $749,710 Co-funding: $149,943 Project Term: June 28, 2013 to March 31, 2015

47 Melaina, Marc, Michael Helwig (National Renewable Energy Laboratory) 2014. California Statewide Plug-in Electric Vehicle Infrastructure Assessment. California Energy Commission. Publication number: CEC-600-2014-003.

Energy Innovations Small Grant Program

Seeding Innovation for Market Success

In addition to large-scale demonstration projects, the Energy Innovations Small Grant Program awards grants of up to $150,000 to test and evaluate new and innovative energy concepts and ideas. The research projects target one of the PIER program's RD&D areas, address a California energy problem, and provide a potential benefit to California electric ratepayers.

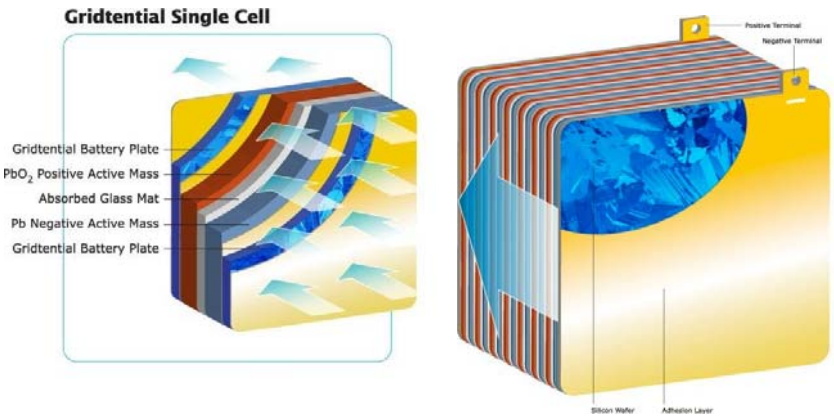
The following Energy Innovations Small Grant Program projects were previously funded proof-of-concept projects that yielded exceptional technical success in 2014. These exciting technical solutions demonstrate the enormous possibility intrinsic to many of the smaller strategic investments made in the energy sector.

The Project: Improving Performance and Decreasing Weight in Lead Acid Batteries

The Issue: The lead acid battery has improved incrementally in ease of use and performance since its invention, but it begins to face significant challenges as diverse applications require high-energy storage density for renewable-generated electricity and advanced transportation technologies. High performance and low weight are key attributes when updating lead acid batteries for newer technologies.

The Research: This project developed new lead acid battery architectures that reduce weight and improve performance. Semiconductor wafers replaced heavy lead plates as the battery electrodes' substrates, and electrochemical processes deposited thin layers of high porosity materials on the plates to improve deep discharge rates. A new structure was implemented to reduce the battery footprint and simplify connecting multiple cells into a battery stack. The researchers' modeling suggested that the new design would lead to performance enhancements and cost advantages compared to current lead acid batteries.

Figure 27: Gridtentials' Single Stack Battery



Gridtentials' single stack battery (R) along with a diagram of a single cell from that battery (L). The single cell is the building block for a battery platform that supports different technologies.

Source: Gridtential

The Benefits: In 2014, Gridtential raised $1.5 million in seed funding based on their Energy Commission small grant work. Along with filing a key patent in five major countries, Gridtential scaled up the development of their 12V Alpha units and recruited both development and Alpha test partners. Most recently, Gridtential announced the launch of its Alpha Program and a Joint Development Agreement with Alpha partner MTD Products, Inc. Driven by consumer demand and the need for an economic, high-performance storage solution, MTD projects current and future applications in the $3 billion market, which includes small-scale vehicles and equipment.

Figure 28: Gridtentials' Alpha Unit Battery

Gridtentials' Alpha Unit 6V Absorbed Glass Mat Battery.

Source: Gridtential

Agreement Number: 500-98-014 Contractor: Gridtential

Project Cost: $95,000 Co-funding: $11,210 Project Term: December 1, 2011 to November 30, 2012

The Project: Increasing Electric Vehicle Range Through the Eco-Routing Navigation System

The Issue: Increasing the use of electric vehicles (EVs) is necessary to diminish the negative environmental and energy impacts associated with conventional petroleum-based vehicles. Unlike traditional vehicles, EVs do not emit any GHG tailpipe emissions. One of the major obstacles to the mass adoption of EVs is range anxiety—the fear that an all-electric vehicle will not make it to a desired destination before running out of power.

The Research: This project demonstrated the eco-routing navigation system for electric vehicles to reduce range anxiety around EVs. The researchers gathered information on real-time traffic information, road type, and road grade on three routes around Riverside, California, to calculate travel routes for EVs that require the least amount of energy. While EVs already provide charging station locations along a chosen route, the eco route considers additional information such as traffic conditions, road type, and grade. The eco-route system uses these features to incorporate all of the variable components of the best possible route, ensuring that the suggested direction is the most efficient trip option at that moment in time. Testing was performed on the ground using a 2013 Nissan Leaf, and once data from the road tests was incorporated into the eco-routing navigation system, the researchers ran models to conduct more than 4,000 trip simulations.

The Benefits: This project showed EV energy savings between 25 and 51 percent when taking the suggested eco-route rather than the most direct route. Although the eco-route may suggest a greater travel distance, it used traffic conditions, road type, and road grade to redirect the driver to the most efficient route. These systems can potentially reduce fuel consumption and GHG emissions from conventional petroleum-based vehicles by up to 15 percent.

"The significant saving in energy consumption, compared to conventional navigation systems, indicate our system, with some future adjustments, has significant potential for commercialization," stated Guoyuan Wu, an assistant research engineer at UC Riverside who was the principal investigator on the project.[48]

As a result of the eco-routing navigation technology, the estimated 7,200 Nissan Leaf EVs sold in California would translate to an annual saving of $4.15 million in electricity costs. If EVs from other manufacturers implement the navigation system, the energy and cost savings would be even greater. In addition, the eco-routing system will decrease EV range anxiety, thus increasing overall EV market penetration.

48 The Engineer. 2014. "Eco-Routing" Could Electric Vehicle Energy Use 51 Percent. http://www.engineering.com/DesignerEdge/DesignerEdgeArticles/ArticleID/8446/Eco-Routing-Could-Electric-Vehicle-Energy-Use-51-Percent.aspx.

Figure 29: UC Riverside's Eco-Routing Navigation System

Source: Dr. Guoyuan Wu, UC Riverside

Agreement Number: 500-98-014 Contractor: The Regents of the University of California, Riverside
Project Cost: $94,714 Co-funding: $0 Project Term: October 1, 2012 to March 31, 2014

CHAPTER 3:
Public Interest Energy Research Delivers Ratepayer Benefits

Public interest energy research, demonstration, and development projects funded by the Commission achieve ratepayer benefits, ranging from reduced GHG emissions to reduced energy costs. These benefits not only provide the ratepayer with cleaner, cheaper energy and accessible innovative technologies, but they advance the state's energy policy goals.

This chapter includes excerpts of in-depth analyses of the benefits of various research efforts in key areas. These retrospective benefits evaluations discuss current savings provided by technologies previously supported by Commission research, including components of these benefits that are directly attributable to the role of PIER Program. Following the analysis section, the current and projected future benefits are described for the overall PIER 2014 research portfolio.

In-Depth Analyses of Technology RD&D and Its Ratepayer Benefits

The Commission conducts in-depth analyses of the benefits provided by select advancements in energy technologies. Many PIER-funded projects have benefits that unfold years after the actual funding of the project, producing continuous benefits in areas including jobs and energy produced and saved. Projects that began 10 to 15 years ago are thriving today, and it is vital to understand the extent to which their benefits are serving California.

Retrospective: Adaptive Technology Lights the Way to Efficiency in California

Background: Lighting constitutes one third of California's commercial electricity use, costing ratepayers more than $5 billion a year. Much of this electricity is wasted when occasionally occupied areas such as hallways remain brightly lit all day, or when areas with multiple light sources, such as offices, provide more light than occupants require (Figure 30). PIER has funded several RD&D projects to reduce this wasted lighting energy use by investing in innovative adaptive lighting technologies that let lighting levels adapt to occupancy and ambient light levels.

Figure 30: Brightly Lit Empty Corridor

Significant lighting electricity is wasted on corridors, which are unoccupied most of the time.
Source: California Lighting Technology Center

Advanced lighting controls for intermittent occupancy

In 2004, the PIER-funded State Partnership for Energy Efficiency Demonstrations (SPEED) Program, in collaboration with the PIER-funded California Lighting Technology Center (CLTC), set out to disseminate a two-level adaptive lighting system for stairwells. SPEED is a PIER program created in 2004 to promote market adoption of energy efficient technologies through demonstrations and other technology transfer projects; CLTC was created at UC Davis in 2003 with PIER funding to foster the next generation of energy saving lighting technologies. CLTC engages in research, development, and demonstration in partnership with the lighting industry, utilities, and government.

From 2004 to 2006, the SPEED program demonstrated the bi-level lighting technology's energy and cost saving benefits, safety, and user comfort on stairwells on ten public university campuses in California. This led to the creation of new adaptive lighting products and to UC and CSU campuses adopting bi-level lighting in corridors, parking areas, and pathways.

Networked wireless lighting controls

Meanwhile, through PIER's Energy Innovations Small Grants program, the Commission was funding proof-of-concept research in intelligent lighting systems for more complicated environments like offices with multiple light sources and diverse occupant requirements. This research started in 2003, when UC Berkeley's Center for the Built Environment (CBE), which is

PIER supported, hosted meetings at which engineering and architectural faculty collaborated with commercial builders and designers to reduce energy use in buildings. Charlie Huizenga, CBE member and UC Berkeley adjunct professor, recognized that lighting electricity use could be greatly reduced in existing buildings by making entire lighting networks respond intelligently to occupancy and light sensors. Because the electrical rewiring was often a cost barrier, Huizenga introduced a novel strategy of installing low-cost controllers in each fixture that used wireless communications to "break the connection between how lighting is wired for power and how it is controlled."[49]

After testing four prototypes in the CBE office space, Huizenga competed for and received a $75,000 Energy Commission Energy Innovations Small Grant in 2004 to test a full personal control system for open office plans. The product was a success, and Huizenga and two graduate business students, Zach Gentry and Josh Mooney, formed Adura to market the technology. Their first customer, UC Berkeley's undergraduate library, achieved investment payback within one year.

From 2006 through 2009 with PIER funding, Adura collaborated with CLTC to further develop and demonstrate a wireless integrated photo and motion sensor product.

Adura ultimately secured more than $25 million in venture capital funding. It was subsequently purchased in 2013 by Acuity Brands Lighting, Incorporated, which now sells the product nationwide as Adura® XPoint™ Wireless. The Xpoint™ lets customers configure lights to respond optimally to daylight and other lights, occupancy cues, user schedules, and/or demand response agreements to save energy and money during peak periods. By summer 2014, Adura/Acuity wireless controllers were installed in nine million square feet of California building space, saving Californians more than 17 million kWh a year and an estimated $1.3 million a year above product and installation costs (Table 2).[50]

49 Huizenga, as cited in: "Lighting It Up, Efficiently." University blog. *University of California Research: Explore Stories*, November 4, 2011. http://research.universityofcalifornia.edu/stories/2011/11/adura.html.

50 All estimates are in real 2014 dollars and assume an 8.06 percent discount rate, a two percent inflation rate, and a conservative ten-year product lifetime. Product values come from kWh saved (14 cents per kWh in 2014, 16.4 cents per kWh in 2020, and intermediate values). Maintenance and peak savings follow the proportions volunteered in the Energy Technology Assistance Program (ETAP) study described below, with peak reduction valued at the capacity residual value of $118 per square foot. Product costs come from early ETAP and from an example given by a manufacturer's sales representative in 2014, with interpolated costs between 2011 and 2014, and 2014 costs staying constant through 2020.

Figure 31: Pleasanton Library with Adura Optimized Lighting

A retrofit with Adura's adaptive lighting controls in the Pleasanton Library is saving 141,000 kWh a year.
Source: Energy Solutions

Huizenga's idea has gone viral. "Since Adura announced their product, other companies started to focus on networked lighting controls and over since 2009, startup and major lighting companies have introduced wireless networked lighting controls," said Karl Johnson, California Institute for Energy and Environment's research coordinator. "Adura was a catalyst to the start of a networked lighting controls industry and, with Zach [Gentry] moving from Adura to Enlighted, helped expand and build the market for these new networked controls."[51]

Founded in 2009 in Sunnyvale, Enlighted has installed hundreds of adaptive lighting systems saving Californians an estimated 44 million kWh a year. Enlighted hopes to grow quickly with its new plan to offer no-money-down financing, recouping investments through energy bill savings.[52] If other vendors follow suit, the entire industry could take off.

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51 Enlighted's blog welcomed Gentry as a pioneer of the wireless lighting control industry. September 28, 2011. http://enlightedinc.com/press/enlighted-appoints-lighting-visionary-as-vice-president-of-marketing-product-management/

52 St. John, Jeff. 2014. "Enlighted Launches Its Smart Lighting Network-as-a-Service". greentechefficiency. https://www.greentechmedia.com/articles/read/enlighted-launches-its-smart-lighting-network-as-a-service.

These savings and those of other wireless networked lighting efforts would not have occurred as quickly (if they occurred at all) without the Commission funding the innovative research that sparked the industry.[53] Asked about the likelihood of realizing his concept without Commission support, Huizenga answered "zero percent."[54]

The SPEED Program and Synergies between Adaptive and LED Lighting

The SPEED program's demonstrations were also critical, proving adaptive lighting provided dollar savings and customer satisfaction. As adaptive lighting technologies developed, the SPEED program demonstrated them in public colleges throughout the state. With SPEED assistance, colleges installed bi-level lighting in spaces with occasional traffic and provided optimized networked systems (such as Adura's) in spaces with varied and complex lighting requirements. At UC Davis, for example, one quarter of lighting energy use was attributed to keeping hallways brightly lit, yet CLTC learned through monitoring that these hallways were vacant 64 to 94 percent of the time. The SPEED Program worked with CLTC to integrate adaptive lighting and more efficient light sources into the campus demonstrations, helping create the market for LED lighting.

Adaptive lighting demonstrations helped bring LEDs to market for two reasons: First, LEDs are the technology of choice for adaptive lighting, as they easily dim to lower lighting levels and work with control units more easily than alternatives; and second, the SPEED Program was able to produce lighting packages where the quick payback from the adaptive controllers made up for the high costs of LEDs. These lighting packages helped colleges balance economic constraints with deep energy savings. SPEED Program Director Karl Brown contends that the synergy between lighting controls and LEDs has created innovation in both and supports a trend toward LED lighting dominating the market. Innovation continues, with the latest SPEED Program demonstrating edge-lit LEDs and luminaire level controls that reduce office lighting to 0.5 kWh per square foot per year in UC Santa Barbara's student services area— a 90 percent reduction from fluorescent lighting without controls.

American Recovery and Reinvestment Act

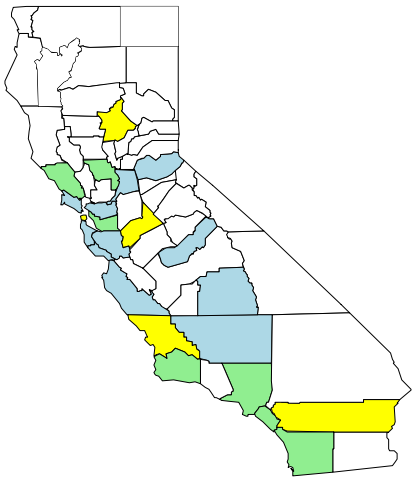
By 2009, when the U.S. government offered economic stimulus money for states with ready-to-go project ideas, the SPEED Program demonstrations had brought adaptive lighting to the forefront. The Energy Commission received funding from ARRA and allocated $6.7 million to create an Energy Technology Assistance Program (ETAP), providing incentives and expertise to increase installations of adaptive lighting systems and other new technologies. From 2010 to 2012, ETAP recipients installed enough adaptive lighting in public buildings, parking areas, and outdoor walkways in 18 California counties to save 11.6 million kWh of electricity a year and at least 940 kW of peak electricity demand (Figure 32). These savings are valued at $825,000 a year

53 Adura was the first company to sell wireless optimized networked lighting. Other companies now selling this system include Exergy and Wattstopper.

54 Interview of Charlie Huizenga, July 30, 2014.

above costs.[55] In total, ETAP funded 52 bi-level lighting projects and twelve wireless controls projects, including 10 Adura projects.

Figure 32: Counties With Adaptive Lighting Installations Funded Through the State Partnership for Energy Efficiency Demonstrations or the Energy Technology Assistance Program



Counties colored yellow benefitted from SPEED demonstrations, those colored blue benefitted from ETAP projects, and those colored green had both. Affected counties include Alameda, Butte, Contra Costa, El Dorado, Kern, Los Angeles, Madera, Marin, Monterey, Orange, Riverside, Sacramento, San Diego, San Francisco, San Luis Obispo, San Mateo, Santa Barbara, Santa Clara, Santa Cruz, Sonoma, Stanislaus, Tulare, and Yolo.

Source: California Energy Commission

Spin-Off Activities

The SPEED Program demonstrations and ETAP projects have led to more adaptive lighting installations as manufacturers increased their production and consumers became familiar and comfortable with the technology. For example, many local agencies receiving ETAP subsidies were reluctant at first to try bi-level lighting in parking garages because they were concerned low lighting levels might encourage criminal activities. Instead, they saw from the earliest ETAP adopters that the fixtures improved lighting quality and uniformity, helping to make the case that bi-level lighting improved safety by signaling movement.

55 All estimates are in 2014 dollars. Costs are amortized using a use a ten-year product lifetime and an 8.06 nominal discount rate, which becomes a 6.01 percent real discount rate given a two percent inflation rate. Utility and ETAP rebates are counted among costs. Net benefits are proportionally low because ETAP was designed to facilitate the market for newer technologies that had not yet reached full market scale.

SPEED program leadership, business cases, and assistance also led to adaptive lighting system installations by the University of California/California State University/Investor-Owned Utility (UC/CSU/IOU) Energy Efficiency Partnership now saving more than 16 million kWh per year. UC/CSU/IOU projects in development will save another 10 million kWh a year, and projects proposed or pending funding could save an additional 23.5 million kWh each year.[56] More importantly, the SPEED Program efforts moved the market toward broad acceptance of adaptive lighting technologies.

Based on these successful demonstrations, the Commission incorporated adaptive lighting for indoor and outdoor applications in its 2013 revision of Title 24 Standards for new construction. These Standards saved an estimated 160 million kWh in 2014, and could save up to 1.3 billion kWh a year by 2020.

In addition, the American Society of Heating, Refrigerating and Air-Conditioning Engineers' (ASHRAE) *Energy Standard for Buildings Except Low-Rise Residential Buildings* (Standard 90.1)[57] also incorporated adaptive lighting control systems for various common areas. This will ensure nationwide dissemination of adaptive lighting technology as ASHRAE standards are used in designing new projects.

Benefits:

Adaptive lighting fostered by Commission RD&D saves 86 million kWh each year from retrofits.[58] Staff estimates these retrofits save $10.7 million a year above amortized costs and reduce carbon dioxide equivalent emissions by 24,000 metric tons (Table 2). Including current and pending UC/CSU/IOU projects, adaptive lighting retrofits will soon be saving at least 96 million to 120 million kWh per year, or $12.7 million to $16.6 million a year above amortized costs, achieving 2.3 to 3.1 percent of maximum feasible potential.[59]

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56 Commission staff estimates assume existing SPEED installation (without fact sheets) costs and return on average the same per kWh as the average among documented SPEED and ETAP applications. Projects in the works are assigned the lower cost assigned to current Adura projects.

57 ASHRAE Standard 90.1-2013 (I-P Edition). *Energy Standard for Buildings Except Low-Rise Residential Buildings*. (ANSI Approved; IES Co-sponsored).

58 These savings are estimated using sales information from two vendors. It is possible that overall savings are much higher considering total adaptive lighting sales in California.

59 Staff estimated maximum feasible potential savings from adaptive lighting retrofits using advanced illumination technologies at 60 percent of the full lighting load of schools, colleges, offices, and warehouses, and of the exterior lighting load of health care institutions and the miscellaneous category that notably excludes retail and hospitality. Staff estimates 34 percent of those savings are due to the controls rather than advanced lighting because ETAP projects had 22 to 46 percent of their savings attributed to the controls. These 34 percent savings constitute the feasible potential retrofit savings of 3.81 billion kWh a year.

Table 2: Realized (2014) Savings in California from Adaptive Lighting Fostered by PIER RD&D

Source of Savings	kWh Saved	kW Peak Avoided	Net Benefits Estimated or Imputed by Staff	Metric Tons CO_2e Saved
Adura Products	17,388,000	At least the 173 listed in ETAP Adura projects	$1,319,000	4,900
Other UC/CSU/IOU Installations	16,640,000	Not reported	$1,958,000**	4,690
ETAP Installations (Not in One of the Above Categories)	7,775,000*	At least 767	$616,000	2,190
Enlighted Products	43,876,000	Not reported	$6,858,000**	12,360
RETROFITS TOTAL	**85,679,000**		**$ 10,746,000**	**24,140**
Standards	160,877,000		$ 18,478,000	45,335
Total Savings in 2014	**246,556,000**	**At least 940**	**$ 29,222,000**	**69,480**

*For savings to sum properly, the ETAP savings of 11.6 million kWh was reduced by 3.8 million kWh, which is captured when ETAP funded Adura and UC/CSU/IOU installations.

**Enlighted and UC/CSU/IOU net benefits are imputed using ETAP and Adura costs.

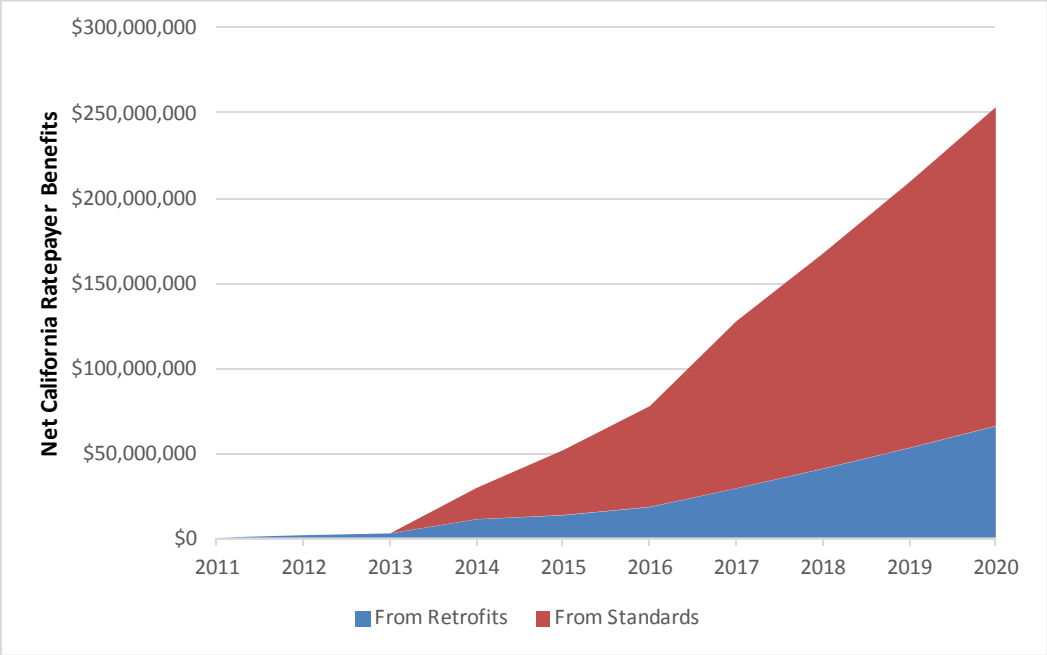
Source: California Energy Commission

There are many reasons for adaptive lighting installations to grow quickly. With all major lighting manufacturers offering adaptive controls, they are an easy add-on to lighting retrofit projects, which are becoming more attractive as LEDs and dimmable fluorescents improve and drop in price. The adaptive lighting industry is growing quickly with good project payback, and easy financing options like Enlighted's will boost sales. In addition, the CPUC's Energy Efficiency Strategic Plan and the Energy Commission's Integrated Energy Policy Report call for all new commercial buildings, and half of existing commercial buildings, to be zero-net-energy (ZNE) by 2030. Adaptive lighting controls will help meet those goals, and the ZNE goals set by a growing number of institutions and local governments in response to climate change. Therefore, it is likely that adaptive lighting retrofits will reach more than 10 percent of their feasible potential by 2020.

By 2020, with retrofits at 10 percent of their feasible potential, adaptive lighting retrofits is projected to save 381 million kWh a year and 107,000 metric tons of GHC a year— $66 million of net benefits above costs annually (Figure 33). Add in adaptive lighting standards, and annual savings for ratepayers could reach $253 million, 1.67 billion kWh, and 471,000 metric tons of carbon equivalent emissions reductions. Considering expected benefits and costs from now through 2020, benefits to ratepayers outweigh PIER expenditures on adaptive lighting research and development 79 to 1.[60]

60 Benefits have a present value of $681 billion. On the cost side, PIER has spent $6 million on lighting demonstrations through SPEED, including adaptive lighting, $75,000 on Adura's small grant, and $2.5 million on the Lighting California's Future grant that funded Adura and CLTC as just one of many

Figure 33: Projected (2014-2020) Annual California Ratepayer Savings from Adaptive Lighting Fostered by PIER RD&D



By 2020, savings on new construction from building standards plus savings in retrofits should save California ratepayers $253 million a year, net of costs. The benefit-cost ratio of California ratepayer savings to PIER expenditures on adaptive lighting RD&D is 79 to 1.

Source: California Energy Commission

projects. The PIER cost used here is therefore an upper bound, making the benefit cost ratio a lower bound.

Overview of the Ratepayer Benefits of the 2014 PIER Portfolio

California ratepayer benefits of PIER-funded electric research are significant and diverse. This report categorizes the PIER 2014 research portfolio, which includes the 151[61] ongoing or completed PIER projects in 2014, by the following benefits:

- **Energy Savings:** conservation and efficiency improvements in the generation, delivery, and consumption of electricity;
- **Reduced Grid Capacity Requirements:** peak demand reductions, load shaping strategies, and other technologies and measures to defer or avoid the need for building new generation, generation, and distribution capacity;
- **Cost Savings:** any reduction in costs for ratepayers, including energy savings and reduced grid capacity requirements, as well as all other sources of cost savings, particularly those arising from innovative technologies, e.g., water savings;
- **Grid Reliability:** reductions in the frequency and duration of outages and enhancements to the quality of power delivered;
- **Climate Benefits**: reductions in GHG emissions and the value of research to forecast and mitigate damage from climate change;
- **Local Environmental and Societal Benefits:** environmental benefits to land, water, and air resources, the protection of cultural and recreational resources, and increases in customer appeal of clean technologies (e.g., health); and
- **Economic Development:** job creation, production of new value streams, increased business investment, and local multiplier effects that arise from cost savings.

Many of these benefits can lead to others, producing a cascading effect. For example, energy savings provide cost savings for ratepayers, and cost savings for ratepayers strengthen California's economy. Energy savings also reduce GHG emissions and air pollutants by avoiding operation and construction of fossil fuel-fired power plants. Reductions in air pollutants, in turn, produce health benefits for ratepayers. Through this systematic approach, this analysis captures the interrelated ratepayer benefits pursued and achieved by PIER.

Estimating the quantitative ratepayer benefits of PIER projects is complex. While many projects have achieved tangible technical successes, additional time is required to commercialize their results, gain market share against established competing products and practices, and provide long-term ratepayer benefits. The uncertainty surrounding the market success of these projects requires conditional assumptions to generate estimates of their benefits; these assumptions are included in the discussion, footnotes, and appendices. Additionally, because approximately 59

61 This number and the following discussion do not include projects managed under the Energy Innovations Small Grants program.

percent of the PIER 2014 research portfolio consists of ongoing projects that will continue into 2015, quantitative data for many projects may not be available until a later time.

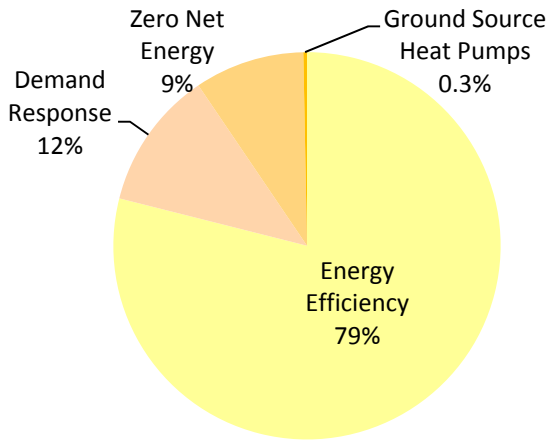
For a subset of PIER projects, the result of the research consists of a report, modeling tool, or other information resource for ratepayers, utilities, or policy makers. In these cases, benefits cannot be quantified until the effect of the information on future decision-making is determined. Instead, the analysis in this report focuses on the ratepayer benefits of the decision-making itself, which is supported by the project.

For these reasons, quantified benefits estimates are only available for a select subset of the PIER 2014 research portfolio. Despite these challenges, the available data strongly support the conclusion that PIER has achieved benefits substantially greater than the amount of ratepayer funds invested. To evaluate the ratepayer benefits of all PIER projects active in 2014, the Commission systematically classified projects by the following attributes:

Research Areas: Research areas reflect the distinct physical components of the electricity system. While most projects fall neatly into one category, some projects address the integration of new technology across two areas and other projects provide analysis relevant to the entire electricity system. For simplicity, every project was assigned a primary research area. The five research areas are: Energy Efficiency and Demand Response; Renewable Energy and Clean Fossil Generation; Smart Grid; Electric Transportation; and the Climate-Energy Nexus.

- **Energy Efficiency and Demand Response:** This research area consists of all projects relating to the consumption of electricity by ratepayers. In total, there are 59 projects classified as primarily related to electricity use in the PIER 2014 research portfolio, accounting for $50.9 million in PIER funding and $30.0 million in match funding, or 59 cents in match funding secured per PIER dollar awarded. Among the five research areas, energy efficiency and demand response was the largest area (based on number of projects and PIER funding), which reflects the priority placed on efficiency resources in California's loading order.

Figure 34: Topics within the Energy Efficiency and Demand Response Research Area

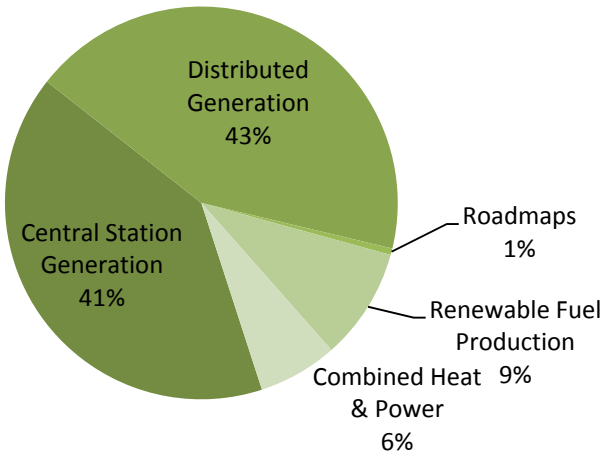


Percentages refer to the proportion of PIER funds budgeted to active projects within the research area.

Source: California Energy Commission

- **Renewable Energy and Clean Fossil Generation:** This research area includes projects that involve any technology (whether owned by ratepayers, utilities, or merchant generators) that generates electricity or another form of energy. This includes efforts to identify, prevent, and mitigate environmental impacts of siting renewable generation and to reduce the emissions from fossil generation. In total, there are 37 projects in this area, accounting for $35.7 million in PIER funding and $43.0 million in match funding. Every dollar of PIER funding committed was matched by $1.20 of funding from private, federal, and other sources.

Figure 35: Topics within the Renewable Energy & Clean Fossil Generation Research Area

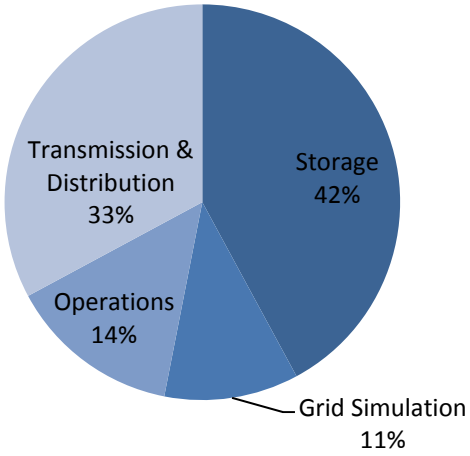


Percentages refer to proportion of the proportion of PIER funds budgeted to active projects within the research area.

Source: California Energy Commission

- **Smart Grid:** This research area consists of projects related to the transmission, distribution, storage, or management of electricity. This includes emerging storage technologies, microgrids, and communications to enable demand response, enhancements to transmission and distribution infrastructure, customer premise networks, and many other technologies to achieve the smart grid. In total, there are 37 smart grid projects, accounting for $37.7 million of PIER funding and $649.7 million in match funding. Among the four research areas, grid systems ranks highest in its ratio of match funding, with every dollar of PIER funding matched by $17.26 of funding from private, federal, and other sources. This large ratio is primarily due to PIER projects that also received ARRA funds from the Department of Energy. The large amount of funds reflects the national commitment to grid modernization efforts.

Figure 36: Topics within the Smart Grid Research Area

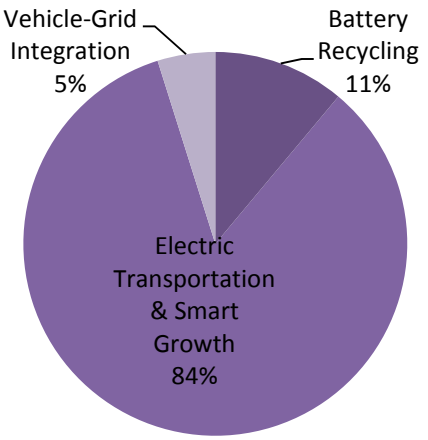


Percentages refer to the proportion of PIER funds budgeted to active projects within the research area.

Source: California Energy Commission

- **Electric Transportation:** This research area includes projects relating to improvements in the efficiency and economics of electric vehicles, vehicle-to-grid applications, and research roadmaps that maximize the value of electrification of transportation in meeting policy goals. In total, three projects are classified as primarily related to transportation, accounting for $2.3 million of PIER funding and $51 thousand in match funding. Every dollar of PIER funding committed was matched by two cents of funding from private, federal, and other sources.

Figure 37: Topics within the Electric Transportation Research Area

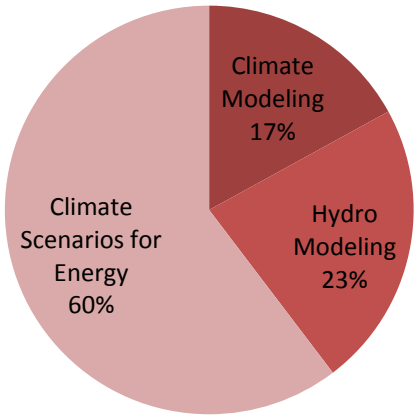


Percentages refer to the proportion of PIER funds budgeted within the research area.

Source: California Energy Commission

- **The Climate-Energy Nexus:** This research area includes projects that inform the public and policy makers on future risks from climate change and mitigation strategies for the electricity sector. There are 4 projects focused in these areas, accounting for $1.8 million of PIER funding and $165,000 in match funding. Every dollar of PIER funding committed was matched by 9 cents of funding from private, federal, and other sources.

Figure 38: Topics within the Climate-Energy Nexus Research Area



Percentages refer to the proportion of PIER funds budgeted within the research area.

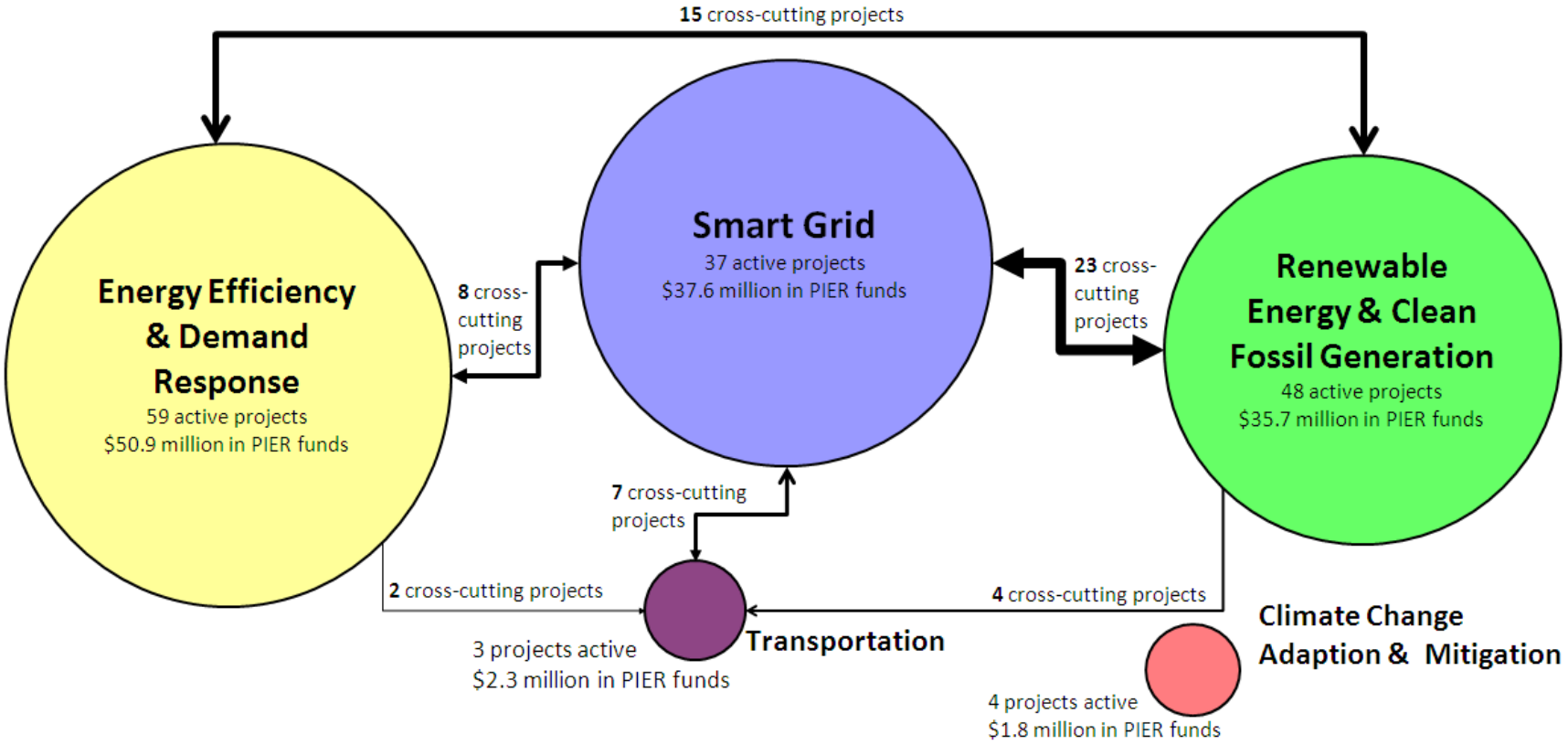
Source: California Energy Commission

Overall, there were 151 PIER-funded projects active or completed in 2014, totaling $135.8 million in funding and $723.0 million in match funding. Every dollar of PIER funding committed was matched by $5.32 from private, federal, and other sources. Figure 39 provides an integrated view of the research areas in the active PIER 2014 portfolio.

End Users – the target market of the research: End users are ratepayers, energy companies, or policy makers who will make use of the research. While the end user varies, all projects are consistent with the guiding principle of PIER, which is to fund research with significant potential for benefits to ratepayers. For example: residential, commercial, and industrial ratepayers are the end users of research to develop new demand response products; utilities and California ISO are the end users of research on managing demand response resources in the context of daily market operations; policy makers are the end users of research on regulatory issues arising from demand response. In all cases, the end users of the research vary while the beneficiary remains the same: the ratepayers. In the PIER 2014 research portfolio, the distribution of funding among categories of end users was as follows:

- **Ratepayers:** Seventy-five percent of funding was allocated toward research whose primary end users are ratepayers, and these projects attracted 28 percent of match funds. This low share reflects the greater need for publicly funded RD&D to deliver innovative products and strategies for use on the customer side of the meter. To address this issue, the PIER program allocates the highest proportion of its funds to projects for this sector.
- **Electricity Suppliers:** Twelve percent of funding was allocated toward research whose primary end users are entities connected to the supply of electricity, including utilities, merchant generators, independent transmission line owners, and California ISO. These projects attracted 71 percent of match funds, which demonstrates comparatively larger private market interest in energy RD&D in products owned and operated by electricity suppliers, rather than by ratepayers. To compensate for this, the largest share of PIER funds are allocated toward projects whose end users are ratepayers.
- **Policy Makers:** Twelve percent of funding was allocated toward research whose primary end user is policy makers, particularly state agencies and local governments. These projects attracted only 0.1 percent of match funding. This low level of match funding indicates the critical role that PIER funds play in supporting public research, which informs California policy makers whose decisions affect ratepayers. The information generated by PIER-funded research enables smarter decision-making to promote greater dissemination of new technologies at a lower cost and environmental impact.
- **Innovators:** One percent of funding was allocated toward research whose primary end users are innovators. These projects attracted 0.9 percent of match funding. Projects of this nature are in the earliest stages of the technology pipeline and require further development before a final product is close to commercialization.

Figure 39: Network Diagram of Research Areas



This diagram shows the relative shares of PIER funding allocated to each research area of the PIER projects active in 2014. The area of each circle is proportionate to the total amount of funding budgeted for the projects with each research area. In addition, the arrows between each research area indicate the number of projects that have a connection to more than one research area ("cross-cutting projects"). Every project is assigned only one research primary research area.

Source: California Energy Commission

Energy Savings

Energy efficiency has been one of California's leading energy policy priorities since the energy crises of the 1970s. The most tangible, direct benefit of energy efficiency for ratepayers is the money saved on their utility bills from reduced energy consumption. However, many other benefits accrue to all ratepayers as a result of those who make energy efficient choices.

Energy Efficiency & Demand Response

Energy efficiency strengthens the economy: According to a UC Berkeley study of the economic impact of California's energy efficiency standards, for every job in the electricity supply sector lost by energy efficiency, 50 new jobs are created in other sectors of California's economy as a result of the increased disposable income available to ratepayers.[62] Furthermore, energy efficiency improves California's balance of trade. A significant portion of California's electricity is imported, as is the fuel for a large fraction of in-state generation. Improvements in the efficiency of electricity production, delivery, storage, and consumption lower the need for energy imports. The money saved by California ratepayers as a result of efficiency is much more likely to be spent in California than money paid to energy suppliers located outside the state. Furthermore, efficiency improvements reduce economic vulnerability to supply disruptions and fuel price volatility.

Energy efficiency protects the environment and public health: While California is investing heavily in a clean energy future; natural gas-fired generation will remain a substantial fraction of the state's electricity supply in the near term. Reductions in inefficient electricity use reduce the need for fossil fuels, thereby reducing their impacts on the environment and public health.

Energy efficiency lowers the barriers to California's clean energy goals: To meet California's clean energy goals, alternatives to fossil fuels must be adopted. Unmitigated growth in energy demand will require larger investments in zero-carbon energy sources. By promoting efficient ratepayer consumption, energy efficiency reduces the need for these alternative energy sources, allowing policy goals to be achieved sooner and at a lower upfront cost.

Overall, 91 projects pursued one or more approaches to benefit ratepayers with energy savings. These projects accounted for 65.4 percent of total PIER funding and 82.2 percent of total match funding, respectively. Of these 91 projects, 52 percent were concentrated in the research area of Energy Efficiency and Demand Response.

To assess the potential energy saving benefits of a wider set of projects in the electricity use research area, data was collected and analyzed to estimate energy savings resulting from products, practices, and building designs developed by PIER projects. Table 2 displays the current annual energy savings from projects. For these seven projects, the estimated energy savings total 133 gigawatt hours (GWh) of electricity and 6.2 million therms of natural gas per

62 Roland-Holst, David. 2008. *Energy Efficiency, Innovation, and Job Creation in California*. Center for Energy, Resources, and Economic Sustainability (CERES), Department of Agricultural and Resource Economics, UC Berkeley. http://www.nextten.org/research/research_eeijc.html.

year. These estimated energy savings correspond to avoided GHG emissions of 44.6 million metric tons of carbon dioxide (CO_2) per year and are estimated to save ratepayers $26.3 million per year. The performance data from PIER-funded demonstrations will encourage the dissemination of new energy efficiency products and practices throughout California, leading to much greater ratepayer savings than those described in Table 3.

Table 3: Current Estimated Annual Energy and Water Savings from a Subset of Completed and Active Projects

Project	Electricity Savings (MWh)	Natural Gas Savings (thousands of therms)	Water Savings (thousands of gallons)	Source of Estimate
Demonstrating Scalable Very Energy Efficient Retrofits for Low Income, Multifamily Housing	150	9		Awardee Estimate During Solicitation: Expert Judgment
State Partnership for Energy Efficient Demonstrations	128,000	5,580		Project Final Report: Realized Benefits from Deployment Program
Primary Effluent Filtration as an Intermediary Wastewater Treatment Step	65			Awardee Estimate Based on Results from Demonstration
Small and Medium Building Efficiency Toolkit and Community Demonstration Program		600		Awardee Estimate During Solicitation: Expert Judgment
Supercritical CO_2 Cleaning and Sterilization of Commercial / Industrial Textile	244	18	20,000	Energy Commission Staff Estimate
Full-Scale Demonstration of an Innovative Electrodialysis Technology for Zero Liquid Discharge Desalination	106		252	Realized Benefits Measured by Awardee During Project
ZNE Demonstration- Integration of Dynamic Daylighting and Passive Cooling/Heating for High Return on Investment	4,375	4.5		CEC Staff Engineering or Modeling Estimate During Solicitation
Total	**132,945**	**6211.5**	**20,252**	

Source: California Energy Commission

In addition to estimate realized and demonstration project savings, the Commission developed estimates of annual energy savings that would be likely to occur by 2020. These estimates refer to projects with a potential for successful commercialization. Table 3 includes such projects, which are in the applied research and development stage as well as the demonstration stage of research.

Table 4: Potential Statewide Energy Savings from a Subset of Projects Likely to be Commercialized by 2020

Project	Electricity Savings (GWh)	Natural Gas Savings (millions of therms)	Other savings	Source of Estimate
More Efficient Residential Heating/Cooling by Airflow Instrument Standards	13			Awardee Engineering or Modeling Estimate During Solicitation
Demonstration of i50 Decentralized Wastewater Treatment/Water Recycling	11		1,800 million gallons of water	Awardee Experiment- or Prototype-Based Estimate During Project
Improving Heating/Cooling Systems with Phase Change Materials	234			Awardee Engineering or Modeling Estimate During Project
Improved HVAC Through Standards for Technician Instruments	27			Awardee Estimate During Project: Expert Judgment
State Partnership for Energy Efficient Demonstrations	3,567	97		Project Final Report: Expert Judgment
Primary Effluent Filtration as an Intermediary Wastewater Treatment Step	11			Awardee Experiment- or Prototype-Based Estimate During Project
Innovative Low-Energy Occupant-Responsive Controls for Heating, Ventilation and Air Conditioning Systems		0.52		Awardee Estimate During Solicitation: Expert Judgment
Small and Medium Building Efficiency Toolkit and Community Demonstration Program	8			Awardee Estimate During Solicitation: Expert Judgment
Supercritical CO_2 Cleaning and Sterilization of Commercial / Industrial Textile*	1.40	1	118 million gallons of water	Energy Commission Staff Estimate
Novel Hydrodynamic Separation Technology for Wastewater Treatment	0.32			Energy Commission Staff Estimate
Envelope Sealing with Adhesive Mist*		212		Awardee Estimate During Project: Expert Judgment
California Plug Load Research Center	10.00			Energy Commission Staff Estimate
ZNE Demonstration- Integration of Dynamic Daylighting and Passive Cooling/Heating for High Return on Investment	1,038.00			CEC Staff Engineering or Modeling Estimate During Solicitation

Project	Electricity Savings (GWh)	Natural Gas Savings (millions of therms)	Other savings	Source of Estimate
Efficient Electronics Through Measurement and Communication	149			Energy Commission Staff Estimate
Central Valley Research Home Program	11			Energy Commission Staff Estimate
High Efficiency Server Fans	0.32			Energy Commission Staff Estimate
Total	**5,080**	**311**		

*Estimates of savings assume forecasts of market penetration. All other projects assume conservatively that 1 percent of ratepayers for whom the technology is relevant will have adopted it by that time.

Source: California Energy Commission

The resulting estimates of annual energy savings for California ratepayers total 5,080 GWh of electricity and 311 million therms of natural gas. Energy savings of this magnitude are estimated to prevent the emission of 3.35 million metric tons of carbon dioxide equivalent (CO_2e) per year and provide $1.4 billion in utility bill savings to California ratepayers.

One project of note is the Central Valley Research Homes project with 11 GWh and 13 MW of estimated potential residential energy and peak savings respectively (see Chapter 2 for more details on the project, titled *Renovating Homes to Increase Efficiency and Reduce Energy Consumption*). Significant migration to the Central Valley of California from coastal areas in the last two decades places stress on the energy resources in the area.[63] This population growth also contributes to increased electricity consumption due to the higher demand for cool homes and businesses. Existing older homes often consume more electricity for cooling as they are often not as efficient as the current Title 24 building standards.

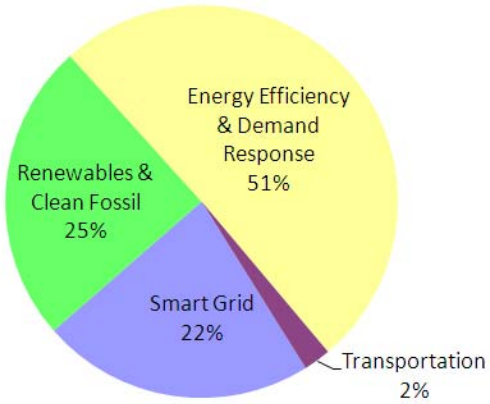
The Central Valley Research Homes project provides valuable insight into the savings potential of heating, ventilation, and air conditioning retrofit measures. Results have been tabulated for four homes in Stockton, California, and measured energy saving have exceeded a 60 percent reduction in cooling energy in all but one of the homes. The oldest home in the study achieved over a 75 percent energy use reduction in cooling, and the newest home in the study, which was built in 2005, provided approximately a 48 percent reduction in its cooling energy use. The newest home most closely reflected the current Title 24 building standard construction, indicating that energy savings can be found even in newer homes. Further application of these valuable energy savings strategies can be employed by Central Valley residents to provide electricity and natural gas bill savings and to lower the overall peak load on hot summer days.

63 Public Policy Institute of California. 2004. *The Central Valley at a Crossroads: Migration and Its Implications.* http://www.ppic.org/content/pubs/report/R_1104HJR.pdf

According to estimates from the 2010 Census, there are over 2.2 million homes in the Central Valley.[64] If the most conservative estimate of air conditioning savings is used from the Central Valley Research Homes Project, then the savings potential would be a 48 percent reduction in air conditioning use per home. The total residential use per year for the 19 counties of the Central Valley is 22,700 GWh. Using disaggregated end-use demand data from SMUD as a proxy for the Central Valley, at least 8.7 percent of total electricity use can be attributed to central air conditioning. Therefore, at least 1,900 GWh of residential use in the Central Valley comes from air conditioning use.[65] If 1 percent of Central Valley homes underwent retrofits with a savings of 48 percent, assuming an annual growth rate of 1.34 percent in electricity demand, California would save over 11 GWh on central air conditioning per year.[66]

Similarly, peak demand reductions ranges from 24 percent in the newest home to 63 percent in the older homes. If 1 percent of the current stock of Central Valley homes underwent retrofits with peak savings of 24 percent or approximately 0.6 kW per home, then a 13 MW peak demand reduction could be achieved in the residential sector of the Central Valley.

Figure 40: PIER Projects with Energy Savings by Research Area



Source: California Energy Commission

Figure 40 summarizes the allocation of PIER funds toward energy-saving innovations by research area, revealing PIER funding priorities throughout the electricity system with respect to energy savings opportunities. Energy savings on the utility-side indirectly pass on lower energy costs to ratepayers and provide societal benefits similar to ratepayer energy savings.

64 U.S. Census Bureau; American Community Survey, 2012 American Community Survey; Physical Housing Characteristics for Occupied Housing Units; generated by CEC Staff; using American FactFinder; <http://factfinder2.census.gov>; (20 October 2014).

65 California Energy Commission; Electricity by County; generated by CEC Staff; using the Energy Consumption Data Management System; <http://www.ecdms.energy.ca.gov/elecbycounty.aspx>; (20 October 2014).

66 California Energy Commission; California Energy Demand 2014-2024 Revised Forecast; CEC-200-2013-004-SD-V1-REV Table ES-1.

Renewable Energy and Clean Fossil Generation

There are 48 PIER projects focused on renewable energy and clean fossil generation that are promoting energy savings, accounting for 25 percent of all energy-saving projects. PIER projects in this research area are promoting energy-saving innovations by:

- Improving the efficiency by which fuel input is converted to electrical output, reducing primary energy consumption;
- Capturing and using waste heat as part of an electric generation process, avoiding unnecessary demand for grid electricity and/or the use of on-site thermal equipment; and
- Avoiding transmission and distribution losses through the use of distributive generation, which provides electricity to ratepayers directly where they use it.

Smart Grid

There are 37 PIER projects dedicated to improving the efficiency of the management, storage, and delivery of electricity to ratepayers. They represent 22 percent of PIER projects that promote energy savings. PIER projects in this research area are promoting energy-saving innovations by:

- Enhancing management of the grid to reduce transmission and distribution losses; and
- Using innovative grid resources, such as storage and demand response, to smooth sudden ramps in electricity demand that would ordinarily be served with inefficient fossil fuel generation.

Electric Transportation

There are three PIER projects dedicated to improving efficiency in the transportation sector. They account for two percent of PIER projects with energy saving benefits. PIER projects in this research area are promoting energy-saving innovations by:

- Promoting smart growth and strategic charging station placement to minimize vehicle miles traveled in the passenger vehicle sector; and
- Guiding future research on using grid-connected electric vehicles as resources for smoothing ramps in electricity demand that would otherwise require fossil fuel generation, and capturing over-generation from intermittent renewable that might otherwise require curtailment.

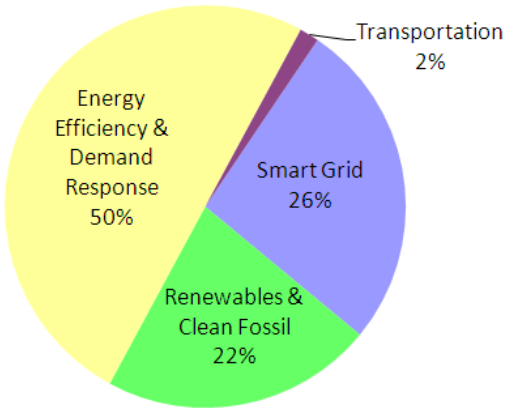
Reduced Grid Capacity Requirements

Because of California's sunny summers, use of air conditioning represents a major driver of peak electricity demand. Periods of peak demand stretch the supply of electricity and cause dramatic increases in the wholesale price of electricity during peak hours. This peak in electricity demand has historically necessitated using inefficient peaked power plants to ensure demand is satisfied at all hours. This form of generation is relatively cheap to build but

expensive to operate. Investments in such plants and the transmission lines needed to connect them with customers are ultimately recouped at ratepayer expense. To minimize these costs, California's energy policy has pursued peak demand reduction in tandem with its overall energy efficiency goals. Furthermore, more recent developments offer tremendous potential to reshape the market dynamics that drive these capital expenditures.

In addition to peak demand reduction efforts, PIER projects continue to provide valuable advances in our understanding of the changing needs of the utility grid. As the penetration of intermittent renewable generation increases to meet the Renewable Portfolio Standard, it is becoming evident that customer and system level resources will need to respond more flexibly to rapidly changing energy requirements. Further, new strategies will be required to meet reliability standards beyond planning efforts focused exclusively on meeting peak demand. The PIER 2014 research portfolio has promoted these developments to reduce infrastructure costs while maintaining or enhancing electricity reliability. There are 59 projects that address peak load reductions through energy efficiency, demand response measures, storage, electric vehicle, and grid technologies.

Figure 41: PIER Projects with Grid Capacity Benefits by Research Area



Source: California Energy Commission

Storage

Energy storage fills the gap between when renewable electricity is generated and when it must be used. Affordable and efficient energy storage could reduce many of the costs of the electricity system by eliminating the need for generation to closely follow demand. The PIER 2014 research portfolio includes 20 projects that advance energy storage, four of which address customer energy management strategies that change the shape of the electricity load throughout the day and across seasons of the year.

As EVs rely on battery storage, there are opportunities to integrate EV batteries with the grid to provide ancillary services. Linking EVs with the grid will simultaneously enable a large pool of energy storage resources to participate in electricity markets and reduce the total cost of EV ownership through lower utility bills. In addition, one project in the portfolio is dedicated to

improving methods for recycling EV batteries, which may contribute to an overall lower cost of EVs and contribute to wider deployment of distributed energy storage resources on the grid.

Demand Response

Demand response introduces another common feature of other energy markets that has not been historically prevalent in the electricity system: it prompts users to use less energy during peak periods, providing even greater ratepayer benefits by allowing for close coordination with grid dispatch operations. The PIER 2014 research portfolio includes seven projects that advance demand response, load shifting, and other strategies to optimize the timing of ratepayer electricity use to minimize cost.

In addition to quantified energy savings, PIER 2014 projects have realized quantified peak demand reductions in demonstration and have tremendous potential to reduce statewide peak demand. These are presented in Table 4, and the discussion of the methodology is found in Appendix B. Demonstration projects active in 2014 have achieved a total of 100 kW in peak reduction, worth around $11,800 in savings per year for ratepayers. Projections of future peak demand reductions total 513 MW of electric capacity. Peak demand savings of this magnitude would produce $60.4 million in savings annually for ratepayers.

Table 5: Estimated Peak Demand Reductions by PIER Projects Active in 2014

Project	Description	Electricity Savings (MW)	Source of Estimate
Low-Cost, Scalable, Fast Demand Response for Municipal Wastewater and Recycling Facilities	Demonstration	0.1	Awardee Estimate During Solicitation: Expert Judgment
Central Valley Research Home	1% of Maximum Potential	13	Energy Commission Staff Estimate
More Efficient Residential Heating/Cooling by Airflow Instrument Standards	10% of Achievable Potential	100	Awardee Estimate During Solicitation: Engineering or Modeling Basis
Control of Networked Electric Vehicles to Enable a Smart Grid with Renewable Resources	1% of Maximum Potential	400	Awardee Estimate During Solicitation: Expert Judgment

Source: California Energy Commission

Distributed Generation

Distributed generation enables ratepayers to become their own electricity suppliers while reducing the need for transmission investments associated with central-station power plants. As with ratepayer-owned storage, ratepayer-owned distributed generation reduces the need for capital expenditures by electricity suppliers and instead enables ratepayers to earn the financial returns on the investment. To lower strain on distribution equipment from surplus electricity exports by distributed generation, PIER has actively targeted research to facilitate bi-directional power flow. Overall, the PIER 2014 research portfolio includes 39 projects that advance distributed generation, particularly rooftop solar PV and combined heat and power (CHP).

Combined cooling, heat, and power (CCHP) builds upon basic CHP by integrating another energy service for added efficiency and value to the ratepayer. An exciting PIER-funded demonstration[67] of the concept is nearing completion on the campus of UC Irvine under the Advanced Power and Energy Program. A fuel cell CCHP system with an electrical capacity of 300 kW and a cooling capacity of 40 refrigeration tons was installed and operated in real-world conditions. Based on the engineering and economic data, this system is financially viable and environmentally friendly. With a combined electrical and thermal efficiency of 74 percent, the annual operation of the system produces virtually no local air pollutants and offsets about 55 metric tons of carbon dioxide relative to grid-supplied energy. Because of its use of advanced fuel cell technology, it qualifies for particularly generous federal tax credits and state incentives. With these incentives, the system is estimated to deliver a benefit-to-cost ratio of 3.8 over its 20 year lifetime for an astonishing 23 percent internal rate of return. Without the incentives, the benefit-cost-ratio equates to 1.7 and the internal rate of return is about 7.8 percent.

67 *Development and Demonstration of a Novel High-Temperature Fuel Cell Absorption Chiller CCHP System*. Agreement Number PIR-09-018. Start Date: 10/25/2010. End Date: 3/31/2015. PIER Funding: $1,480,000. Match Funding: $2,140,000.

Reducing Ratepayer Costs

California's energy goals represent a vision for the future that could not be achieved by private market forces alone. While much of the private investment in RD&D for renewable energy has been limited by the well-established market position of fossil fuels, PIER has funded innovation in all four research areas to drive down the total cost of renewable energy and energy efficiency. Two examples of PIER's work to reduce the cost of renewable energy include:

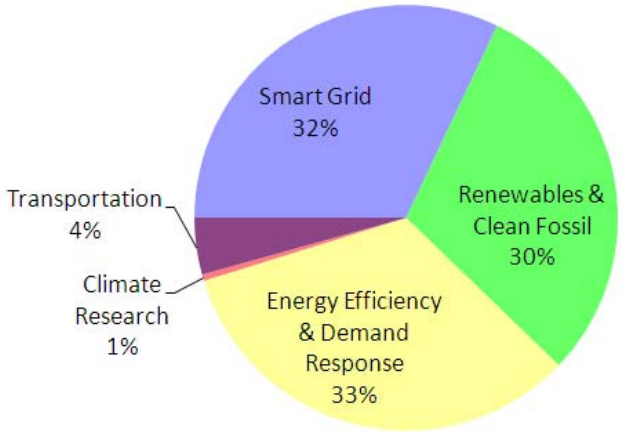
- ***Wind Ramp – Short-Term Event Prediction Tool – Development and Implementation of an Analytical Wind Ramp Prediction Tool for the California Independent System Operator:*** Conducted at UC Davis, this project builds on a previous PIER project that developed a data tool for California ISO to predict sudden changes in wind generation.[68] This project will further refine the tool and analyze historical data from wind resource regions in California to improve the accuracy and value of the information provided by the tool to California ISO. As a result, the amount of quick-start back-up generation needed to integrate intermittent wind energy into the electric grid will be reduced, lowering ratepayer costs.
- ***Technologies For Extracting Valuable Metals and Compounds From Geothermal Fluids:*** Conducted by Simbol, Inc., this project is working to demonstrate a method for recovering metals such as lithium, manganese, zinc, potassium, cesium, and rubidium from the working fluid of geothermal power plants in the Imperial Valley.[69] For further validation of their method, they will attempt to manufacture lithium-ion batteries from the recovered material. This will create a new valuable income stream for geothermal power plants, helping to offset the cost of renewable geothermal energy.

These cost reductions benefit ratepayers who adopt new technologies, as well as other ratepayers who benefit from lower costs incurred by utilities to meet their statutory and regulatory obligations to minimize their environmental impact.

68 Agreement 500-11-009.

69 Agreement PIR-10-059.

Figure 42: PIER Projects with Cost Savings by Research Area



Source: California Energy Commission

Reducing Greenhouse Gas Emissions and Mitigating the Impact of Climate Change

Research funded by PIER strongly supports the central goal of California's energy policy, which is to address the increasing disruption to the earth's climate caused by anthropogenic GHG. Primarily, PIER projects advance new technologies, strategies, and information that will promote the dissemination of zero-carbon alternatives to meet the state's energy demand. Additionally, PIER research is dedicated to benefitting ratepayers by minimizing the damage to California's economy, natural resources, and quality of life resulting from climate change and its important impact on energy infrastructure.

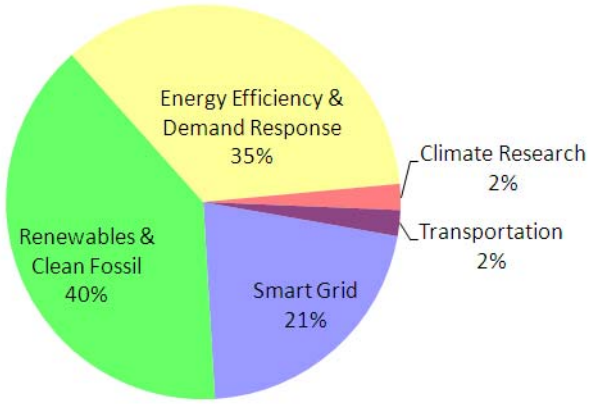
The PIER 2014 research portfolio to reduce GHG emissions spans all four major research areas: electric use, electric generation, electric grid systems, and electric transportation. The electric generation category includes 14 projects to address the impact of climate change in California. These projects relate to carbon capture and sequestration as well as climate science.

One project that relates electricity generation to greenhouse gas emissions is UC San Diego's *Investigation of Discrepancies in Regional Climate Projections for California*.[70] Past PIER research has shown that the electricity sector—including generation, delivery infrastructure, and consumption—is vulnerable to climate change. This project will ensure greater accuracy and consistency of forecasts to ensure appropriate planning of the future electricity system at minimum ratepayer expense.

Based on quantitative estimates of energy savings from energy saving projects presented earlier in this report, it is possible to estimate reductions in greenhouse gas emissions from California's electricity system. The energy savings of PIER projects in Table 3 would reduce CO_2-equivalent GHG emissions by 3.35 million metric tons of CO_2e per year, assuming the estimated levels of market penetration were achieved.

70 Agreement number 500-12-001.

Figure 43: PIER Projects Providing Climate Benefits by Research Area



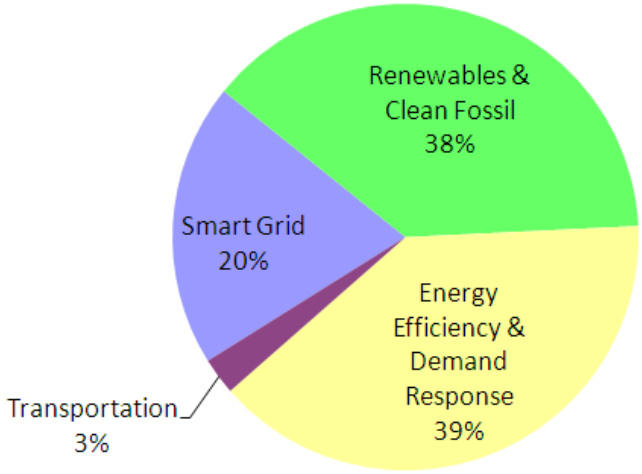
Source: California Energy Commission

Local Environmental and Social Benefits

In addition to addressing the threat of global climate change, California's energy policies include goals to protect the state's fresh water supply, air quality, flora and fauna, scenic beauty, and public health from the environmental impacts of energy use. Commission research has studied energy-related environmental impacts and advanced clean energy solutions to address them. PIER projects active or completed in 2014 that support these environmental goals occur across the research areas of electricity use, electric generation, electric grid systems, and electric transportation.

In total, 10 projects in the PIER 2014 portfolio were identified as conserving water resources. These projects include efficient building designs that conserve energy and water simultaneously, novel wastewater treatment technologies that slash energy requirements and enable new sources of water recycling, and energy-efficient industrial processes that eliminate the need for water altogether.

Figure 44: PIER Projects Providing Environmental or Societal Benefits by Research Area

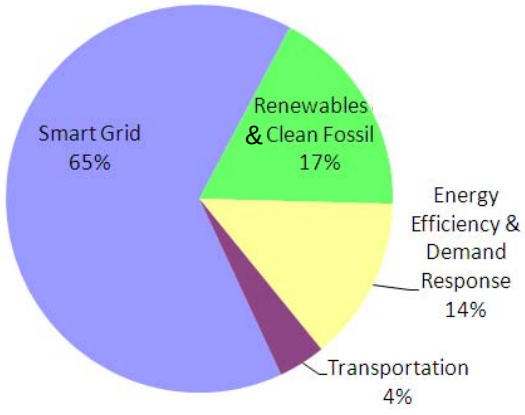


Source: California Energy Commission

Enhancing Grid Reliability and Power Quality

California ratepayers require reliable, high-quality electric service to power a modern standard of living. A study by Lawrence Berkeley National Laboratory estimates that the typical small business suffers an economic loss of $314 from a momentary interruption of electric service and $665 for an outage lasting one hour.[71] To promote reliability and quality improvements throughout the electricity system, PIER conducted relevant research across all areas, with the primary focus on electric grid systems. Of the 37 total projects in this research area, 25 include reliability among their benefits.

Figure 45: PIER Projects Providing Reliability Benefits by Research Area



Source: California Energy Commission

71 Dollar values are adjusted using the GDP deflator to present estimates for 2013. Source: Sullivan, Michael J. 2010. *How to Estimate the Value of Service Reliability Improvements.* Lawrence Berkeley National Lab. LBNL-3529E. http://certs.lbl.gov/pdf/lbnl-3529e.pdf.

Stimulating Economic Activity and Employment

As discussed throughout this chapter, the PIER research portfolio provides numerous and often interrelated benefits to California's ratepayers. One noteworthy economic benefit is the extent to which PIER reinvests ratepayer funds into California's economy. Of the 151 projects active or completed in 2014, 145 were carried out by researchers in California. Of the few projects conducted outside the state, many included facilities in California where a new technology was installed and demonstrated.

Table 5 tabulates the direct employment of California workers resulting from PIER funding for projects active in calendar year 2014. These numbers include employment over the lifetime of each project; the average project lasted about 3.2 years. In total, an estimated 1,580 California workers were directly employed, either full- or part-time, by the PIER 2014 research portfolio. The total number of hours worked is equivalent to roughly 665 person-years[72] of full-time work. Over their entire duration, these projects will pay an estimated $73.8 million in wages and benefits to California workers.

Table 6: Measures of Employment by PIER 2014 Projects in California

Measure	Estimate
Persons Employed, part or full-time	1,580
Years of Full-Time-Equivalent Work	665
Wages & Benefits Paid	$73.8M

These estimates refer to budgeted values. Dollars are not inflation-adjusted.

Source: California Energy Commission.

PIER not only stimulates employment in California, but provides valuable experience and training to workers. A total of 57 projects were identified as contributing to workforce development, such as employing college students in hands-on research or developing curriculum for workforce training. In particular, seven projects were dedicated to providing green job training, such as the *California Smart Grid Workforce Development Network – Strategic Plan*[73] being developed at CSU Sacramento, which not only better prepares California workers for future jobs, but it also enhances the quality of work performed on behalf of ratepayers.

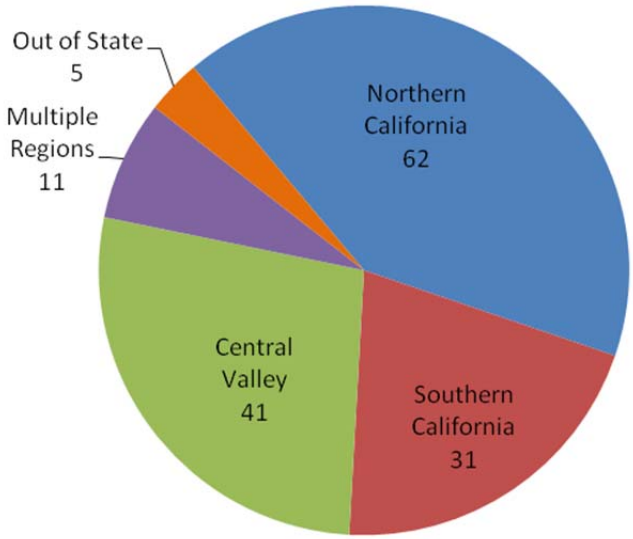
Since PIER was funded by ratepayers across California, the Commission strives to reinvest program dollars broadly back into the regions of California. This is subject to the overriding priority of the program, which is to fund the most promising RD&D with the potential for benefits to ratepayers. Because technical expertise is often concentrated in geographic clusters, the geographic distribution of projects and funding in a given year may not always neatly align in proportion to California's population. It should also be noted the overwhelming majority of

72 One full-time-equivalent work year is approximated here to be 1,911 hours, which represents a 40-hour work week with 10 holidays and 12 days of other leave or vacation.

73 Agreement 500-11-011. More information available here: http://sgworkforce.ecs.csus.edu/.

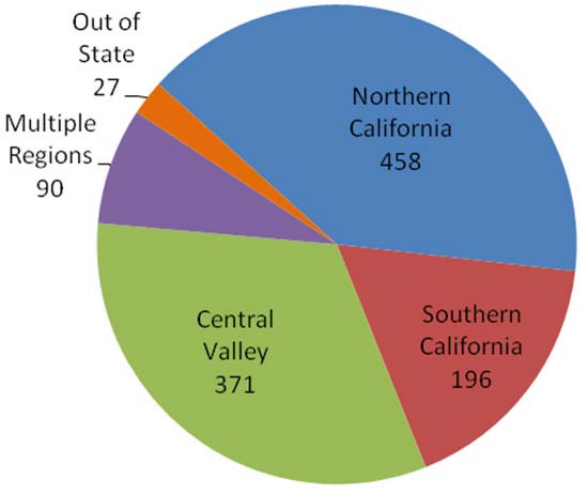
projects are conducted by contractors located in California. Figures 46 through 48 provide an overview of the geographic distribution of the impact of PIER projects active in 2014.

Figure 46: Number of PIER Projects active in 2014 by Region



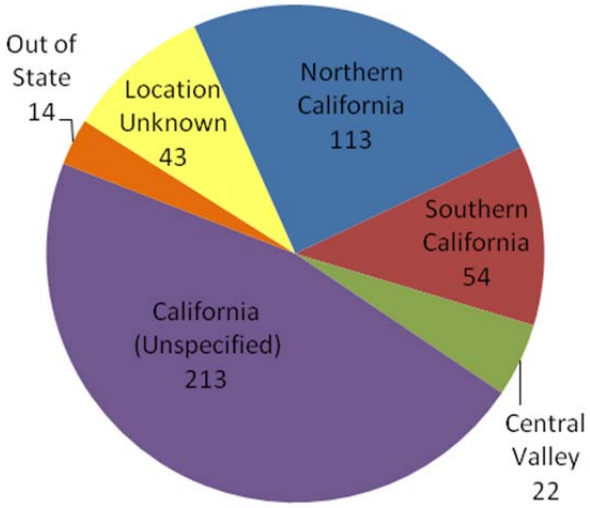
Source: California Energy Commission

Figure 47: Regional Distribution of Prime Contractor Jobs Reported by PIER Projects Active in 2014



Source: California Energy Commission

Figure 48: Regional Distribution of Subcontractor Jobs Reports by PIER Projects Active in 2014



Source: California Energy Commission

Another important indicator of PIER's future economic benefits to California is the jobs that will be created directly by the successful development and commercialization of new energy technologies. This is in addition to the economic growth resulting from all successful PIER-funded projects will indirectly create jobs in all sectors of the economy through cost savings, improved health, and avoided climate change damages for ratepayers. The following discussion

considers direct employment in California's electricity-related sectors resulting from PIER research. These job estimates are preliminary, and the ultimate impact on employment will be determined by the commercial success of PIER-funded technologies in future years.

Commission staff identified 10 projects— a subset accounting for $11.8 million in PIER funding and $320.4 million in match funding— as having the potential to create future, long-term jobs in California directly associated with the manufacture, sale, installation, maintenance, or operation of clean energy technologies. The total estimated jobs sum to 5,634 jobs, which equates to an average rate of one job created per $2,100 of PIER funding, spent and $56,900 in match funding leveraged.

For comparison, the Congressional Budget Office scored ARRA at a cost to the federal government of $830 billion over the years 2009-2019. The Congressional Budget Office estimated that ARRA resulted in the creation of between 0.9 and 4.7 million full-time-equivalent jobs (including indirect and induced jobs) at the peak of its impact on the U.S. economy in 2010, after which the effect on employment began to diminish.[74] Using the high estimate, this equates to one temporary, full-time job per $176,600 spent. Based on the multiplier effects used by the Congressional Budget Office for spending on renewable energy and energy efficiency,[75] the 5,634 direct jobs potentially created by successful PIER projects would result in an additional 2,817 indirect and induced jobs, bringing down the cost to $39,300 in PIER and match funding per job created.

74 Congressional Budget Office. 2014. *Estimated Impact of the American Recovery and Reinvestment Act on Employment and Economic Output in 2013.* https://www.cbo.gov/sites/default/files/45122-ARRA.pdf.

75 Ibid. See Table 2 for estimates of the multiplier effect associated with Division A, Title IV, of the law relating to energy. The estimates range from 0.5 to 2.5; the middle of this range is (1.5) is chosen for the purposes of this discussion.

CHAPTER 4: Conclusion

The rational pursuit of creativity and innovation in California's energy landscape has yielded and will continue to provide enormous returns on the investments made. The PIER Program has proven its ability to leverage its own investment funds to bring in private and federal dollars and create jobs while helping California build toward its planned energy future. The innovations funded by PIER save electricity ratepayers millions of dollars every year, through improved system reliability, higher energy efficiency standards and codes, and the use of PIER-developed technologies and tools. Californians have benefited from products brought to the marketplace to reduce energy demand and costs, enhance generation performance, increase comfort and public safety, reduce environmental waste streams, and promote clean air. The projects highlighted in this report have directly addressed barriers facing policy goals, sometimes even transforming and advancing the policies themselves, as in the case of PIER energy efficiency research.

As a significant influence on the world's economic and energy future, California has taken the leadership role of supporting aggressive policy goals and funding innovative energy projects that result in emerging technologies, standards, and strategies. The Energy Commission has invested more than $738 million for energy research and development through the PIER Electric program and leveraged its investment to attract more than $1.3 billion in match funding, reaping benefits that far outweigh the costs. Nobel laureate Robert Solow estimated that more than 90 percent of economic growth comes from investments in innovation. The private rate of return on RD&D is around 20 to 30 percent, while the social rate of return is around 66 percent.[76]

Over the last 16 years, the PIER Program responded to evolving policy goals and market needs. The program initially focused on research involving individual components and progressed to emphasize integration of multiple energy technologies to solve complex, interrelated issues and to maximize synergies and benefits. The program also enhanced its capabilities and processes in regards to collection and reporting of benefits data.

PIER has been one of the premier energy research programs in the country and one of only a two state programs of its kind. PIER research has been vital in the transformation of the state's energy policy landscape, providing clear and quantifiable results that policy makers and innovators have used to plan for the future. Although the PIER Electricity Program is not funding new projects, its investments laid a foundation for continued progress toward California's clean energy future. The complexities and challenges of transforming the energy system that powers California are enormous; they must continue to be matched by capable, strategic, and comprehensive investment in innovation.

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76 Nemet, Gregory F. "Policy and Innovation in Low-Carbon Energy Technologies." Ph.D. dissertation, May 2007. https://mywebspace.wisc.edu/nemet/web/Thesis.html.

GLOSSARY

Term	Definition
ACH50	air changes per hour under 50 Pascals of pressure
ARB	Air Resources Board
ARRA	American Recovery and Reinvestment Act
BWP	Burbank Water and Power
California ISO	California Independent System Operator
CBE	Center for the Built Environment at UC Berkeley
CO_2	carbon dioxide
CPUC	California Public Utilities Commission
EPIC	Electric Program Investment Charge
EV	electric vehicle
GHG	greenhouse gas
GWh	gigawatt hour(s)
HiGRID	Holistic Grid Resource Integration and deployment
HVAC	heating, ventilation, and air conditioning
kW	kilowatt(s)
kWh	kilowatt hour(s)
MW	megawatt(s)
MWh	megawatt hour(s)
PEF	Primary Effluent Filtration
PIER	Public Interest Energy Research
PV	photovoltaic
RD&D	research, development, and demonstration
RFB	redox flow battery
RPS	Renewables Portfolio Standard
SMUD	Sacramento Municipal Utility District
WCEC	Western Cooling Efficiency Center
WWTP	wastewater treatment plant
ZEV	zero-emission vehicle
ZNE	zero-net-energy

APPENDIX A:
List of Projects Active or Completed in 2014

Title:	New Technology for Ground Source Heat Pumps				
Agreement Number:	500-08-042	Project Number:	2	Research Stage:	Applied Research
Electricity Funding:	$200,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	8/1/2012	End Date:	12/1/2014	Technology Topic:	Ground Source Heat Pump
Award Recipient:	Western Cooling Efficiency Center - UC Davis			End-Market:	Ratepayers

Description:

The main objective of this project is to evaluate and, if successful, publicize the cost effectiveness and performance of new alternative drilling systems for ground source heat pumps that could significantly reduce the installed first cost of these heat pumps. The key attraction of this project is that the reported cost reductions, if proven out, could make Net Zero Energy homes possible at reasonable first-cost premiums, while also providing significant peak electric demand reduction, and eliminating the need for natural-gas pool heating in some instances.

Objectives:

1. Thermal analysis of the various alternative piping/ground-interface systems
2. Field testing of the performance of the different alternatives (including heating and cooling season performance)
3. Investigation of the practicality of including swimming pools for a portion of the heat rejection/capture for these installations
4. Perform a detailed cost-effectiveness analysis of the various alternatives
5. Estimate overall energy and peak demand savings potentials for the state of California
6. Prepare reports for publishing and download from the WCEC website
7. Present at ASHRAE functions, local utility energy centers, and other venues

Benefits:

This project will reduce both natural gas and electricity consumption, as well as reduce peak electricity demand. Ground source heat pumps replace natural gas and facilitate the use of solar for heating and cooling purposes, thereby facilitating Net Zero Energy buildings. Injecting waste heat into swimming pools reduces natural gas consumption for pool heating.

Title:	Envelope Sealing with Adhesive Mist				
Agreement Number:	500-08-042	Project Number:	3	Research Stage:	Applied Research
Electricity Funding:	$100,000	Match Funding:	$0	Natural Gas Funding:	$200,000
Start Date:	8/1/2012	End Date:	12/1/2014	Technology Topic:	Whole Building
Award Recipient:	Western Cooling Efficiency Center - UC Davis			End-Market:	Ratepayers

Description:

Provide better building envelope tightness levels and automated documentation of tightness at considerably lower cost than current manual envelope sealing methods. Provide quicker, less-expensive compliance with codes, reduced infiltration loads (heating and cooling), and peak electricity demand savings.

Objectives:

1. Analysis of the implications of aerosol envelop sealing from the point of view of building energy efficiency codes in new and existing residential and commercial buildings

Conduct lab tests of the application of appropriate sealant materials. Although the existing duct sealing material can seal envelope leaks, this effort will entail using the UC laboratory facility (test "box" with 8-ft ceiling) to test the sealing performance of alternative materials that meet the various codes and standards. The alternative materials include those that dries harder than the duct sealant. A large building-sealant manufacturer will provide appropriate sealant materials for testing.

Develop alternative hardware for sealing. This effort will look at using stand-alone aerosol injectors in combination with a standard blower door to produce the sealing.

Estimate overall energy and peak demand savings potentials for the state of California. Existing studies and models of residential and commercial buildings will be used to evaluate the savings associated with tighter envelopes.

Estimate the cost-effectiveness of the technology, and compare the cost (e.g., cost per square foot) versus the energy cost savings (e.g., savings per square foot)

Field testing and application protocol development for different building applications. This effort will first explore the practical implications of applying the technology in different situations. Items to be investigated include: a) how many different injectors are needed for a particular application, b) how much air mixing is required (e.g. oscillating fans), c) how to best cover the floor during injection, and d) how to treat leaks that we do not want to seal (e.g. taping certain gaps in double-hung windows). These efforts will be used to develop protocols that will then be tested by commercial firms

7. Identification of any code compliance issues (e.g., fire, electrical) or other barriers to overcome to achieve maximum penetration

Benefits:

The results of work funded to date have enabled development of new application systems and protocols, and testing of new injection methodologies and sealants that have dramatically improved performance over earlier systems. Sealing now takes far less time to accomplish withimproved sealing performance. Over the course of this research, sealing efficiency has gone from covering 60% of a structure's leaks to over 80%, and the time to achieve this sealing has dropped dramatically as well, providing the type of progress that will greatly enhance the processes transition into the marketplace.

Title:	Phase Change Materials for Hydronic Heating Systems				
Agreement Number:	500-08-042	Project Number:	4	Research Stage:	Applied Research
Electricity Funding:	$50,000	Match Funding:	$0	Natural Gas Funding:	$100,000
Start Date:	8/1/2012	End Date:	12/1/2014	Technology Topic:	Whole Building
Award Recipient:	Western Cooling Efficiency Center - UC Davis			End-Market:	Ratepayers

Description:

The goal is to increase the hydronic systems energy efficiency by replacing the water heat transfer medium with a water-phase change material (PCM) to increase the heat transfer capacity.

Objectives:

Apply the hydronic-system retrofit to at least one building. This will include recruiting appropriate sites, engineering required to successfully apply the technologies, including satisfying any owner/operator concerns, and seeing that the work is properly carried out.

Measure the performance of the technology and the energy savings that it provides (both gas and electricity). This activity will include non-energy measurements to assess the performance of the technology. Determine project cost effectiveness (capital cost versus energy cost savings) for the application.

Develop tool for analyzing the expected performance and cost effectiveness in other hospitality buildings, as well as estimate the overall energy saving potential for California and barriers to overcome in order to realize the potential.

4. Publicize a successful outcome through posting full reports on WCEC website for download, develop case study/fact sheets and reports, outreach to other hospitality facilities and organizations and other venues, including ASHRAE and local utility energy centers.

Benefits:

Phase change materials can be added to hydronic systems to increase the thermal carrying capacity of the water circulating through the hydronic system. If the circulating "slurry" can survive both mechanical and temperature cycling for sufficient periods of time, it can dramatically reduce the pumping power needed to circulate the slurry. Modeling suggests power savings of over 40%, but this real-world demonstration will be used to assess how the system performs in a real world application. If pumping power can be substantially reduced, in both heating and cooling applications, the hospitality industry would be able to save significant amounts of the energy currently used to condition their facilities.

Title:	Opportunities for Gray Water Re-Use				
Agreement Number:	500-08-042	Project Number:	5	Research Stage:	Applied Research
Electricity Funding:	$150,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	8/1/2012	End Date:	12/1/2014	Technology Topic:	Water Efficiency/ HVAC
Award Recipient:	Western Cooling Efficiency Center - UC Davis			End-Market:	Ratepayers

Description:

WCEC is investigating the benefits and feasibility of using harvested rainwater as a strategy to reduce tap water consumption in highly efficient, California climate-appropriate evaporative cooling systems. The low hardness levels in rainwater compared to municipal tap water would minimize scale formation, which wouild extend the evaporative system life and increase system efficiency. This results in reduced consumption of water (at both the municipal and system level), electricity, and chemicals, and reduced water treatment needs (such as water softening). As an added benefit, the storage and use of rainwater for cooling could help manage urban residential storm water runoff while providing an alternative residential water source.

Objectives:

Determine viability of rainwater capture for use in residential evaporative systems

2. Observe and analyze the water quality of the reclaimed rainwater while stored for over 6 months.

Determine the levels of potential contaminants and whether the water would need further treatment to be used in evaporative systems or for irrigation.

4. Test and analyze the effect of reclaimed rainwater on evaporative systems

Benefits:

Evaporative systems are proven to be much more energy efficient and peak efficient than standard HVAC systems. Some of the trepidation from market forces for these systems is the issue of water-use (especially during times of severe draught like in California), and system longevity. Rainwater reclamation removes the need to use municipal water for evaporative systems. Rainwater may have a significantly less deleterious effect on evaporative systems, thus improving their reliability and longevity; ultimately increasing the overall viability, and desirability of evaporative systems.

Title:	Personal Comfort Systems (PCS)				
Agreement Number:	500-08-044	Project Number:	2	Research Stage:	Applied Research
Electricity Funding:	$300,000	Match Funding:		Natural Gas Funding:	$0
Start Date:	8/1/2012	End Date:	12/31/2014	Technology Topic:	HVAC/ZNE
Award Recipient:	Center for the Built Environment - UC Berkeley			End-Market:	Ratepayers

Description:

The goals of project #2 are to demonstrate the energy and comfort impacts of personal comfort systems (PCS) in different types of buildings, both conventional and energy-efficient; to demonstrate how PCS should be integrated with existing building controls to harvest the energy-saving made possible by PCS; and to influence the manufacturing of future PCS through presentations to the building industry and specifications for clients and standards organizations.

Objectives:

1. Conduct 3 case studies to demonstrate the comfort and energy performance of personal comfort systems
2. Conduct 2 case studies in near ZNE buildings with radiant slab systems
3. Conduct laboratory experiments to compare cooling loads between radiant and air systems
4. Conduct simulation study to investigate impact of climate and control strategies on radiant system performance

Benefits:

Project #2 will provide evidence of the comfort and energy performance of PCS, solutions to identified barriers to implementation, specifications for clients and standards organizations, leading to the promotion of PCS technology in the marketplace.

Title:	Space Conditioning in Near Zero-Net-Energy (ZNE) Buildings				
Agreement Number:	500-08-044	Project Number:	3	Research Stage:	Applied Research
Electricity Funding:	$300,000	Match Funding:		Natural Gas Funding:	$0
Start Date:	8/1/2012	End Date:	12/31/2014	Technology Topic:	HVAC/ZNE
Award Recipient:	Center for the Built Environment - UC Berkeley			End-Market:	Ratepayers

Description:

The goal of project #3 is to provide to the professional design community new and improved information, guidance, and tools for designing and operating near ZNE buildings using radiant heating and cooling systems. This will be accomplished by conducting two thorough case studies of existing near ZNE buildings using radiant systems, conducting a series of laboratory experiments to improve our understanding of the fundamentals of radiant systems, and by performing whole-building energy simulations using EnergyPlus, allowing a sensitivity analysis of climate and control strategies.

Objectives:

1. Conduct 3 case studies to demonstrate the comfort and energy performance of personal comfort systems
2. Conduct 2 case studies in near ZNE buildings with radiant slab systems
3. Conduct laboratory experiments to compare cooling loads between radiant and air systems
4. Conduct simulation study to investigate impact of climate and control strategies on radiant system performance

Benefits:

Project #3 will provide to the professional design community new and improved information, guidance, and tools for designing and operating near ZNE buildings using radiant heating and cooling systems. The empirical evidence that will be collected from case studies will include a) energy performance, b) cost, and c) occupant perception of the indoor environment in order to compare radiant systems with other buildings, establish the basis for more accurate potential energy savings estimates, and provide design firms and owners real world project examples.

Title:	Realizing Energy Efficient Lighting in California				
Agreement Number:	500-08-053	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$5,011,481	Match Funding:	$870,000	Natural Gas Funding:	$0
Start Date:	6/30/2009	End Date:	3/30/2015	Technology Topic:	Lighting

Award Recipient:	California Lighting Technology Center - UC Davis	End-Market:	Ratepayers

Description:

The goal of this Agreement is to conduct a set of research activities that follow the successful pattern the UCD California Lighting Technologies Center (CLTC) has followed since its establishment in 2004 to very effectively develop new lighting technologies and bring them to the market. Development of new technologies requires several phases, starting with initial laboratory prototypes and ending with commercial products. These phases include laboratory and field testing of laboratory and commercial prototypes and then pilot installations of commercial products to demonstrate feasibility and benefits towards market adoption. This also requires significant outreach in the form of educational and training activities.

Objectives:

1. Produce a group of products, technologies and knowledge that will meet specifically outlined PIER goals of improving energy cost/value by developing energy-efficient light technologies and bringing them to the market through research, development, outreach, and technology transfer activities.

Benefits:

Improve energy cost/value by developing energy-efficient lighting technologies and bringing them to the market . Strengthen California's economy by partnering with the lighting industry, lighting professionals, the electric utility community, the building industry, and other governmental agencies. Conduct outreach and technology transfer activities, in collaboration with utilities, industry, and academic and professional institutions.

Title:	High Performance Building Façade Solutions - Phase 2				
Agreement Number:	500-09-026	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$3,000,000	Match Funding:	$6,000,000	Natural Gas Funding:	$0
Start Date:	3/15/2010	End Date:	3/31/2014	Technology Topic:	Whole Building
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Ratepayers

Description:

The project will develop, or support the development and deployment of promising near-term and emerging zero-energy building (ZEB) façade technologies for solar control and daylighting of commercial buildings, addressing two of the largest end uses in California commercial buildings: cooling and lighting. The work will focus on both technology development and tools development.

Objectives:

1. Develop, or support development and deployment of, promising near-term and emerging zero-energy building (ZEB) façade technologies for solar control and daylighting of commercial buildings
2. Investigate integrated façade solutions that meet aggressive energy and peak demand goals while satisfying indoor environmental quality (IEQ) requirements
3. Facilitate deployment and development of innovative technologies and new simulation tools

Benefits:

The objective of this work was to support industry's development and deployment of both incremental and breakthrough façade technologies in partnership with the U.S. DOE. The project directly supported the R&D efforts of individual industry partners but also developed core measurement and modeling capabilities that will benefit the entire fenestration industry for years to come.

Title:	Education Software for Workforce Development				
Agreement Number:	500-09-046	Project Number:	1	Research Stage:	Technology Development
Electricity Funding:	$1,986,715	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/30/2010	End Date:	3/30/2014	Technology Topic:	Whole Building
Award Recipient:	Institute for Sustainable Building Performance (DBA) Institute for the Sustainable Performance of Buildings			End-Market:	Ratepayers

Description:

The purpose of this project is to improve the ability of the buildings industry to deliver and operate energy-efficient commercial buildings by enhancing the education and training of architects, mechanical designers, commissioning providers, service technicians and building operators. The approach is to develop and distribute open-source, free software products to provide substantial computer-based resources and tools for assisting in workforce development. The areas include HVAC system operation, controls and troubleshooting, lighting, daylighting and lighting controls and integrated design of sustainable buildings. The target audiences are students in community colleges, students in four year colleges and universities and technicians, operators and design professionals. Different variants of the tools were developed for different audiences at different levels. The project builds on previous collaborations between SuPerB and LBNL funded by the NSF Advanced Technological Education program and by the California Energy Commission.

Objectives:

Transform building performance in the commercial sector by raising the problem-solving and troubleshooting skills of technicians, building operators, commissioning agents, architects, engineers, and other building industry professionals

Develop and disseminate web-based education software tools and resources to California technicians, building operators, educational institutions, and organizations with in-house energy education programs

3. Develop tools that can be used either individually or in group learning situations

All products developed are either open source or web-based public domain delivery platforms, ensuring their widespread use and their potential extension and modification by others

5. All tools and resources developed are intended to be available at no cost to users

Benefits:

The five software development projects in this overall Learn High Performance Buildings program project will together make an immediate impact to the State of California by providing an alternative mechanism to train building technicians, operators, building managers, designers, contractors, and energy service providers to enhance building delivery and operations. The software has the potential to reach a much larger audience much faster than classroom training alone.

The improved education and training from an advanced suite of educational software could substantially improve the distribution and depth of knowledge and skills in the workforce about energy efficiency and could thus help to transform both the delivery and the operations and maintenance of commercial buildings in the State of California.

Title:	Healthy Zero Energy Buildings Program				
Agreement Number:	500-09-049	Project Number:	1	Research Stage:	Policy/Regulation Support
Electricity Funding:	$3,400,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	8/9/2010	End Date:	3/15/2015	Technology Topic:	Indoor Air Quality
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Policymakers/ Regulators

Description:

The goal of the Health Zero Energy Buildings program is to provide high quality research in ventilation and indoor environmental quality (IEQ) that will assist the California Energy Commission in developing standards that simultaneously provide for occupant fresh air needs and keep energy demands to a minimum.

Objectives:

1. Develop survey methods to measure ventilation, indoor and outdoor pollutant source contribution to indoor concentrations, building control system impacts on IEQ, and their combined impacts on building occupant health, comfort, performance, and productivity
2. Assess how ventilation rates affect human outcomes in commercial buildings
3. Quantify the energy costs of ventilation in California commercial buildings
4. Develop a process for selection of thresholds for acceptability of human outcomes

Develop recommendations on setting minimum ventilation rates for Energy Commission, standards bodies, and other stakeholders as appropriate

Benefits:

This program will produce and interpret scientific information on ventilation rates necessary in commercial buildings to maintain the health, comfort, and performance of occupants. The key products of the research will be:

- New techniques to measure ventilation, indoor air quality, building occupant health, comfort, and productivity.
- Development of a much-needed database of indoor air quality in commercial buildings in California.
- Understanding of the sources and dynamics of key indoor pollutants that are controlled through ventilation.
- Increased knowledge of the relationship between ventilation and human outcomes.
- New information on energy costs of ventilation in commercial buildings.

The findings in this program will assist in developing science-based ventilation standards that support the health, comfort, and performance of building occupants while limiting unnecessary over-ventilation of buildings. This information is needed for setting policy and standards on the design and operation of energy efficient buildings. Information will be available for use by Energy Commission Standards, ASHRAE, and other standards bodies for use in setting science-based ventilation rates that protect human health.

Title:	Central Valley Research Home Program				
Agreement Number:	500-10-014	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,882,091	Match Funding:	$880,000	Natural Gas Funding:	$0
Start Date:	9/27/2010	End Date:	3/15/2015	Technology Topic:	Whole Building
Award Recipient:	Bruce Wilcox			End-Market:	Policymakers/ Regulators

Description:

Use 4 different vintage homes in the Central Valley to test and measure the effects of retrofit solutions including envelope and HVAC, and duct reconfiguration. Measure how individual measures reduce cooling and heating related energy use. Rank and prioritize measures by effect and life cycle costs/savings.

Have multiple HERS raters estimate baseline energy use and examine the accuracy or inaccuracy and range between raters with actual energy use compared to the estimates. Have multiple HERS raters estimate post-retrofit energy use and examine the accuracy or inaccuracy and range between raters with actual energy use compared to the estimates. Suggest changes to procedures and software to improve future estimates of baseline and post retrofit energy use.

Objectives:

Identify and characterize alternative [conditioned air] distribution systems
2. Produce a technology transfer plan
3. Improve HERS software to produce better estimates of existing home pre and post retrofit energy use
Develop life cycle cost effective residential retrofit packages that will reduce heating and cooling energy use by 50 percent or more in experimental homes in the Central Valley climate zones

Benefits:

Improved HERS rating accuracy for estimating retrofit measure energy savings or whole house energy savings.
Demonstrate significant savings on heating and cooling from installing a package of retrofit options. Demonstrate the savings possible from off-the-shelf current technology or approaches including whole house fans, caulking and sealing, and super insulating attics and crawl spaces.

Title:	Large Scale Residential Retrofit Program				
Agreement Number:	500-10-015	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,224,994	Match Funding:	$1,000,000	Natural Gas Funding:	$0
Start Date:	9/15/2010	End Date:	2/28/2014	Technology Topic:	Retrofits
Award Recipient:	Davis Energy Group, Inc.			End-Market:	Ratepayers

Description:

This project is developing a roadmap for achieving economies of scale and streamlined processes for the home retrofit industry, which has historically been limited by a case-by-case, custom approach to improving the energy efficiency of existing single family homes.

Objectives:

1. To estimate the impacts of the large scale residential retrofit program (LSRRP), the problem should be split into two categories: houses that will actually receive retrofits through the efforts of the LSRRP; and houses that are likely to benefit by the after effects of a successful demonstration program. To estimate the benefits of the proposed project in California, a simulation program using Building Energy Optimation (BEopt), was used to determine savings for a typical home built in 1990s, of approximately 1,800 square feet in climate Zone 12, to exceed California Energy Commission's Title 24 Building Standards

Three "packages" of energy efficiency measures were developed based on the BEopt analysis of the example house. The first package includes window film, attic insulation, weatherization, duct tightening, and lighting upgrades; the second adds an air

Benefits:

This demonstration exhibited an average estimated savings of 570 kWh (6.9%) and 53 therms (9.7%) per home. Of the 12,345,233 California households, a market potential of 2.064 million single family homes are estimated, excluding homes without air conditioners, rental homes, recently remodeled homes, and low cooling energy users. Applying the savings estimated in this analysis to the 2 million homes results in an estimated market potential annual savings of 1,178 GWH and 1.09×10^8 therms.

The Large Scale Residential Retrofit Program also provided valuable lessons for the administration of future retrofit programs, such as program flexibility and having professional sales staff trained in building science. Professional sales people with experience selling to homeowners, such as real estate agents, have the skills needed to convince homeowners that energy upgrades are in their interest. Additionally, a "big bold" public campaign is needed to build homeowner awareness of the benefits derived from home energy upgrades, and economic incentives must be rationalized. Once the playing field is shifted, uptake of residential retrofits can go viral, making a very significant contribution toward reducing peak energy demand and GHG emissions.

Title:	Unique Multifamily Code-Relevant Measures for the 2014 Title 24 Energy Standards Update				
Agreement Number:	500-10-019	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,270,830	Match Funding:	$608,800	Natural Gas Funding:	
Start Date:	10/11/2010	End Date:	3/31/2014	Technology Topic:	HVAC/glazing
Award Recipient:	Benningfield Group			End-Market:	Ratepayers

Description:

To review California energy code standards that relate to multifamily buildings in 2 areas: Ventilation and Fenestration (glazing) and to test the energy savings potential using smart control thermostats and information displays to save money in multifamily apartment units. The project included a standards review, market characterization, and the ventilation and smart control projects included some field work. Project results would be used to suggest changes to improve the building energy efficiency code or to assist building designers or operators.

Objectives:

1. Characterize the existing stock of multifamily bldgs. with respect to ventilation, heating and cooling configurations
2. Demonstrate performance and air quality improvements of alternative ventilation design technique
3. Propose ventilation related code changes for energy savings
4. Characterize the existing stock of multifamily bldgs. with respect to fenestration characteristics
5. Collect field data on fenestration, area, orientation and performance ratings
6. Survey fenestration manufacturers
7. Quantify the energy savings potential of in-home energy monitor and display systems in multifamily buildings
8. Inventory and compare Smart Home Energy Monitor technologies available

Analyze field study data on effectiveness of smart controls and in-home information devices to reduce energy or peak demand related to cooling control

Benefits:

Improves and simplifies the understanding of energy code requirements for multifamily building designers/builders. The information gained from this project helped to better define the differences and similarities between residential, commercial and multifamily construction. Additionally, a control study done as part of this project demonstrated that programmable thermostats displaying rate information to multifamily building tenants can result in lower summer peak demand for air conditioning when compared to those who did not have these devices and information.

Title:	Using Advanced Power Electronics to Save Energy in Consumer Electronics and Motorized Appliances				
Agreement Number:	500-10-022	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,856,899	Match Funding:	$500,000	Natural Gas Funding:	$0
Start Date:	4/1/2011	End Date:	4/1/2014	Technology Topic:	Whole Building
Award Recipient:	Electric Power Research Institute (EPRI)			End-Market:	Ratepayers

Description:

The goal of this agreement was to promote market adoption of more efficient power electronics technologies in key consumer (plug load) product categories to include: induction cooking, home audio equipment, kiosk and multimedia computers, adjustable-speed drive applications in motorized appliances, and electronic devices currently lacking power-factor correction.

Objectives:

To provide CA with tools to reduce energy from electronic and motorized products

Benefits:

Reduced energy use and demand for electronics and motorized devices.

Title:	Natural Ventilation for Energy Savings in California Commercial Buildings				
Agreement Number:	500-10-025	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,900,000	Match Funding:	$200,000	Natural Gas Funding:	$0
Start Date:	11/22/2010	End Date:	10/31/2014	Technology Topic:	Ventilation
Award Recipient:	The Regents of the University of California, San Diego			End-Market:	Ratepayers

Description:

The goal is to enable the introduction of natural ventilation in non-residential buildings in California and achieve the consequent energy savings and greenhouse gas emissions. This improvement in the energy performance and indoor environmental quality in existing commercial buildings in California will be gained by assessing the benefits of, and the barriers to, the use of natural ventilation and by providing improved analysis tools to design practitioners.

Objectives:

1. Characterize Market
2. Characterize Air Quality and Comfort
3. Computer Modeling

Benefits:

Improved understanding of the performance of natural ventilation in non-residential buildings will move the market closer to broader of adoption, enabling energy savings.

Title:	Integrated Retrofit Solutions for Untapped Markets				
Agreement Number:	500-10-028	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,995,032	Match Funding:	$1,197,500	Natural Gas Funding:	$0
Start Date:	3/31/2011	End Date:	12/31/2014	Technology Topic:	Whole Building
Award Recipient:	The Regents of the University of California, Davis			End-Market:	Ratepayers

Description:

California needs wide scale deployment of whole-building energy efficiency retrofits in every sector of the economy to meet the State's goals for increasing energy efficiency, reducing peak demand and meeting AB 32 reduction targets for greenhouse gas emissions. Multi-tenant light commercial (MTLC) buildings pose a particular challenge, in part because the business and technical needs in this market are diverse and complex and, in part, because information to meaningfully characterize the market is limited and disaggregate. Success for energy efficiency requires sophisticated research about the technical and business needs in this market followed by development of technology innovation and delivery mechanisms that are tailored to those needs. The goal of this project is to develop technological and market-based approaches that are cost-effective, and commercially viable, and that address whole-building, integrated technology and financing solutions that include building envelope, lighting and heating ventilation and air conditioning including integrated controls.

Objectives:

Develop baseline understanding of Multi-Tenant Light Commercial Building Market
2. Identify existing and emerging Envelope, Interior and Exterior Lighting technologies
3. Identify, investigate and test with developed tools the potential HVAC improvement opportunities including downsizing potential
4. Identify potential retrofit packages for a subset of MTLC buildings, test certain things in the lab
5. Secure demonstration sites, baseline measure, install packages of appropriate Lighting, Envelope and HVAC technologies, monitor and analyze results

Benefits:

This project will result in a turnkey retrofit package of energy efficiency measures tailored for multi tenant light commercial buildings, such as small shopping malls and neighborhood center. These retrofit packages will reduce energy use, energy costs and lower peak demand for this sector.

Title:	Advanced Combined Cooling Heat and Power for Building Efficiency				
Agreement Number:	500-10-048	Project Number:	2	Research Stage:	Applied Research
Electricity Funding:	$385,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	7/1/2011	End Date:	6/30/2014	Technology Topic:	CCHP
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Ratepayers

Description:

The goal of this project is to develop engineering tools for designing and operating combined cooling, heat and power (CCHP) systems by analyzing, optimizing and documenting performance of an existing CCHP system using natural gas-powered fuel cells, liquid cooled photovoltaic cells, absorption cooling, heating, and thermal energy storage at the University of California Irvine (UCI).

Objectives:

Acquire dynamic data from a commercial absorption chiller, high temperature fuel cell, and solar power installations existing on the UCI campus

2. Acquire corresponding data to characterize dynamics of electrical, heat and cooling demand of an existing representative campus building

3. Analyze the thermodynamics and dynamics of the chiller, fuel cell and solar power data

Develop tools for conceptualizing, analyzing and designing integrated absorption chiller, high temperature fuel cell, and solar power systems and prepare a report on the tools

5. Demonstrate the technical feasibility and economic viability of novel integrated fuel cell, absorption chiller, and solar CCHP systems

Benefits:

This project will develop tools and methods that will improve the performance of CCHP technologies from fuel cells, solar PV, solar thermal and other distributed generation technologies.

Title:	Improving Heating/Cooling Systems with Phase Change Materials				
Agreement Number:	500-10-048	Project Number:	4	Research Stage:	Applied Research
Electricity Funding:	$275,024	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	7/1/2011	End Date:	12/31/2014	Technology Topic:	Whole Building
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Ratepayers

Description:

This project evaluates the effectiveness of adding encapsulated phase change beads to water distribution systems whose purpose is to transport or distribute heating or cooling. The project was designed to evaluate various factors that could influence the effectiveness, including the impacts of thermal cycling and pump-induced shear stresses on the beads, the impact of the beads on pumps, pump power, valves, and heat exchanger performance, as well as thermal losses from piping. The work includes laboratory testing, and supports a field test in an actual hydronic system funded under a different contract.

Objectives:

1. Conduct a literature review and study of the fluid dynamics of the proposed system
2. Evaluate and select appropriate PCMs for further study
3. Conduct a study of existing pumping technologies and assess their suitability for use with PCMs
4. Prepare a report on literature review and PCM evaluation
5. Develop a test protocol for laboratory evaluation of performance of PCM based fluids
6. Design and select equipment for a prototype system
7. Build a laboratory test system and prepare a report on experimental design for laboratory testing
8. Conduct a laboratory test of PCM based fluids
9. Disseminate results through the heating and air conditioning industry, demonstrate the benefits of the proposed system
10. Prepare a report on hydronic cooling including laboratory test results and project conclusions

Benefits:

The benefits of this project are expected to be realized first in the large hotel market, which uses water distribution to make heating and cooling simultaneously available to a large number of separate heat exchangers. The key benefit is expected to be a drastic reduction (>60%) in pump power, as the phase change material increases the thermal capacity of the water by a factor of 3 to 5. In addition to pumping power benefits, there could be other benefits with respect to thermal losses from the circulated fluid, and the performance of heat exchangers (e.g. chillers and boilers). Other applications should include large commercial buildings, education campuses, health care facilities, all of which use water for distributing heating and cooling. In addition, the technology could provide the same benefits in industrial or agricultural applications that uses water to transport significant amounts of energy.

Title:	Mini-Channel Technology to Improve Solar Water Heaters				
Agreement Number:	500-10-048	Project Number:	5	Research Stage:	Technology Demonstration
Electricity Funding:	$333,202	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	7/1/2011	End Date:	12/31/2014	Technology Topic:	Water Heating
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Ratepayers

Description:

The goal of this project is to design and manufacture a solar water heater with a mini-channel heat exchanger, and a round-tube flat-plate (RTFP) solar water heater, to demonstrate the improved performance, and to analyze the market for the technology and determine design changes needed to ease mass production of the mini-channel-based solar water heater.

Objectives:

Design and build a 1.8m2 (19.3 ft2) mini-channel solar water heater
2. Perform tests and measure its performance for all four seasons of the year
Demonstrate improved efficiency of mini-channel water heater performance compared to an actual standard round-tube flat-plate solar water heater

Benefits:

This project aims to reduce the initial costs of solar thermal systems. Solar thermal water heating in California can have 2 or 3 times the cost of the highest efficiency gas water heater which gives them unrealistically long payback periods. Reducing the first cost of solar water heating has the potential to shorten payback periods which would make it a more attractive technology. Lowering costs would allow for wide spread adoption which would facilitate the significant reduction of electrical and natural gas energy, air emissions and GHGs.

Title:	Saving Energy in Buildings With Adaptive Lighting Systems				
Agreement Number:	500-10-048	Project Number:	7	Research Stage:	Applied Research
Electricity Funding:	$275,017	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	7/1/2011	End Date:	12/31/2014	Technology Topic:	Indoor Lighting
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Ratepayers

Description:

This project develops retail lighting solutions that ensure lights are off or dimmed when no occupants are present or when there is available daylight, a concept known as adaptive lighting. This project will reduce lighting energy use by identifying which spaces in retail buildings are most suitable for adaptive lighting and then developing and testing systems, using either existing or experimental lighting devices.

Objectives:

Develop and field test adaptive lighting systems for retail buildings aiming at integration with other building systems
Integrate research projects that maximize the value of building energy RD&D by incorporating technology and market evaluation with demonstration and deployment
3. Achieve energy and peak demand savings in retail buildings
4. Advance adoption of adaptive lighting devices through increased volume from integration into sector-specific packages
5. Increase exposure of the public to adaptive lighting energy-efficient technologies

Benefits:

Adaptive lighting solutions have been demonstrated to save over 50% in applications such as corridors and exterior applications. This concept would save California a substantial amount of electricity if widely deployed in retail buildings.

Title:	Saving Energy in Buildings With Adaptive Envelope Systems				
Agreement Number:	500-10-048	Project Number:	8	Research Stage:	Applied Research
Electricity Funding:	$274,999	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	7/1/2011	End Date:	12/31/2014	Technology Topic:	Whole Building
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Ratepayers

Description:

The project goal was to reduce energy use in retail buildings by promoting widespread adoption of envelope solutions which actively manage ventilation and daylight, in coordination with electric lights and HVAC systems, a concept known as an adaptive envelope system. The research team developed a package of systems that incorporate advanced control components and algorithms that will reduce energy and peak demand savings.

Objectives:

1. Develop and field test adaptive envelope systems for retail buildings aiming at integration with other building systems
2. Integrate research projects that maximize the value of building energy RD&D by incorporating technology and market evaluation with demonstration and deployment
3. Advance market adoption of research products through development of inter-linked projects that are technically feasible, providing a cost effective approach that is connected to the market through manufacturers, customers, builders, regulators and other market actors
4. Achieve energy consumption and peak demand savings in retail buildings

Benefits:

This project will help address this problem by developing, testing and integrating cost effective solutions to optimize the integration of windows, skylights and shading systems with HVAC and electric lighting systems. The research team will develop a package of systems that incorporate advanced control components and algorithms that will reduce energy and peak demand savings. This project promotes the policy goals contained in the Integrated Energy Policy Report (IEPR), Public Resources Code Section 25620.1 (b) (2), AB-32 and the CPUC/CEC Energy Efficiency Strategic Plan by developing technology to reduce the energy use of retail buildings.

Title:	Improved HVAC Through Standards for Technician Instruments				
Agreement Number:	500-10-048	Project Number:	9	Research Stage:	Applied Research
Electricity Funding:	$305,604	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	7/1/2011	End Date:	12/31/2014	Technology Topic:	Whole Building
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Ratepayers

Description:

Installing and maintaining air conditioners in residences and small commercial buildings requires somewhat sophisticated instrumentation, to fine tune the amount of refrigerant, and to identify system shortcomings that might reduce energy efficiency. The ultimate goals of this project are to assess the adequacy of the instruments typically used in the field, and to facilitate the adoption of more suitable instrumentation and suitable methods of using these instruments, and thereby increase energy savings. This is accomplished through lab testing, demonstration, development of best practices, education on best practices, and dissemination of product information generically. The project will have a significant impact on the energy performance of residential and small commercial building HVAC by providing information to contractors, technicians, utility program managers and policymakers about appropriate tools and techniques.

Objectives:

1. Develop and launch a laboratory that will:
   - Lead a standard-setting process for field instruments,
   - Conduct research on measurement methods,
   - Educate technicians on appropriate tools and techniques,
   - Disseminate information on tools and techniques through a website and publications, and
   - Provide instrument testing.
2. Reach out to the industry to ensure that the research is meeting commercialization needs,
3. Solicit funding from industry entities for subsequent activities.

Benefits:

The improvements in new and existing HVAC enabled by this project will save on the order of 170 GWh/year in the residential and small commercial sectors, corresponding to a cost savings of $43M/year and a carbon savings of 46 million kg CO_2e/year. The results of this project will also help to create more comfortable buildings, better indoor air quality, and longer lasting AC equipment.

Title:	State Partnership for Energy Efficient Demonstrations				
Agreement Number:	500-10-049	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$2,515,918	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/30/2011	End Date:	12/30/2014	Technology Topic:	Whole Building
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Ratepayers

Description:

The State Partnership for Energy Efficient Demonstrations (SPEED) was a collaboration of the University of California, California State University, California Community Colleges, federal, state and local governments, and others to maximize the deployment of PIER technologies. The SPEED Program conducted field demonstrations of PIER technologies that have had minimal or no demonstrations. These demonstrations intended to prove technical and financial efficacy and encourage uptake of PIER-funded technologies. SPEED also provided marketing and industry outreach support. The SPEED program demonstrated and facilitated the market adoption of energy-efficient end-use non-residential technologies, including several PIER-supported technologies. The program gained working experience with new technologies, to enable informed decisions about deployment of new technologies at scale.

Objectives:

Demonstrate PIER technologies, applications knowledge, and information tools in strategic venues to the building design, operations, and maintenance professions—communicating program results through web-based and selected other information resources.

Plan and coordinate PIER technology demonstrations and scaled deployments to meet the utility and customer (needs), focusing on comprehensive deep efficiency retrofits and addressing new construction application when possible.

Provide cost and performance analysis of PIER technology in comparison with conventional equipment and make this information available in easy-to-use resource(s) to facilitate decisions by potential users. This includes documentation of ratepayer benefits (such as lifecycle analysis of energy and cost saving , maintenance savings and costs) when compared to conventional equipment/systems.

Assess maintenance, replacement, renovation, and new construction opportunities in consideration of customer cost and performance requirements, and develop business-case proposals for PIER product applications.

Explore leveraging funding opportunities from other sources to help develop attractive customer business cases—such as Investor-Owned Utility (IOU) Partnership programs, utility rebates and incentive programs, applicable loan or bond financing opportunities, and federal grants.

Develop and publish pre- and post-case technology fact sheets that describe the technology, measured performance, energy use and cost information (cost benefit analysis), and document occupant satisfaction.

Benefits:

The project validated performance of PIER-supported and other new energy efficiency technology through demonstrations. The project accelerated technology adoption for PIER-supported and other technologies through demonstrations, development of business cases, and assistance with pilot scaled deployments.

Title:	Urban Heat Island Mitigation Phase 2				
Agreement Number:	500-10-052	Project Number:	5	Research Stage:	Applied Research
Electricity Funding:	$392,727	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	9/1/2011	End Date:	1/31/2014	Technology Topic:	Planning
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Ratepayers

Description:

The project goal was to increase the adoption of cool roofs, cool pavements, and shade trees as 'cool community' measures through the expansion and dissemination of research about their benefits, including energy savings, and CO_2 emission reductions. This will be done by creating codes, assisting with city implementation programs, and outreach and education efforts to other agencies such as Caltrans.

Objectives:

1. Continue the cool roof study and demonstration project
2. Continue the cool pavement study and demonstration project
3. Update and maintain the website that serves as a one-stop source of cool roof information
4. Update and continue cool-community courses and develop new resources for stakeholders
5. Expand outreach, develop model codes, and provide technical assistance to key stakeholders
6. Quantify benefits of cool community measures by estimating decreases in local air temperature

Benefits:

This project demonstrated the benefits of cool community strategies and drove interest in the cool community voluntary measures. In Fresno, California, the team evaluated the benefits of cool roof tiles relative to the standard home. LBNL found that the annual site energy savings for the cool roof home were 26 percent. In the cool pavement demonstration, the team found that more reflective pavement surfaces decrease the pavement temperature and thus reduce the heat that is convected and emitted to the environment. By applying local climate models to Bakersfield, the team found that the deployment of cool roofs and cool pavements reduced maximum air temperatures by 0.3 °C over the downtown area. To increase the voluntary adoption of cool community measures, outreach and technical assistance drove interest in these measures and led to several new pilot projects, policies, and programs in line with California's emission reduction goals. These activities produced a range of benefits for California's ratepayers by reducing utility bills, improving air quality and enhancing urban livability.

Title:	Efficient Electronics Through Measurement and Communication				
Agreement Number:	500-10-052	Project Number:	9	Research Stage:	Applied Research
Electricity Funding:	$392,727	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	7/1/2011	End Date:	3/14/2014	Technology Topic:	TV
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	

Description:

Develop a communicating power supply to enable communication of energy information to a building management system or other central entity. Assign each power supply or device a unique identifier that can be recognized by a building energy management system or networked entity. Miniaturize these functions into a single chip and get this concept included into future technical specifications for Energy Savings programs, such as Energy Star.

Objectives:

1. Create a communicating power supply that can communicate energy use information for all kinds of plug in devices.

Benefits:

The information from this project will help develop an industry standard for electronic products equipped with switched mode power devices that can transmit energy use information to building operators through building management systems. This information can be used to make corrections on equipment operations to reduce energy use.

Title:	Building Air-Tightness Through Appliance Venting Standards				
Agreement Number:	500-10-052	Project Number:	12	Research Stage:	Applied Research
Electricity Funding:	$382,909	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	7/1/2011	End Date:	6/30/2014	Technology Topic:	Ventilation
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	

Description:

Air sealing of homes to reduce the uncontrolled entry of outdoor air is typically among the most cost-effective home retrofit measures to reduce energy consumption and associated greenhouse gas emissions. However, tighter homes more readily depressurize when exhaust ventilation equipment is operated, making combustion appliances more prone to backdraft and spill harmful exhaust gases into the living space. This project used a literature review, field measurements, and computer simulations to show that existing "worst case depressurization" based diagnostic tests are fundamentally flawed and that new tests need to be developed to identify when flows stall in combustion appliance vents and to assess the statistical variation of spilled pollutant concentrations and associated health risks.

Objectives:

Identify recent advances in combustion safety metrics, diagnostics, and norms, with particular emphasis on recent research and publications related to vent system resistance, wind effects, and simulation of vent system performance

Develop a method of calculating the probable maximum depressurization that can be expected and whether sustained backdrafting and spillage could occur

3. Field tests and simulations of new diagnostic method (replaced with field tests and simulations of new risk-based theory)

4. Develop diagnostic guide and advise standards bodies (replaced with work in number 3)

Take the diagnostic procedure and guidance developed in this task to American Society for Testing and Materials (ASTM) Performance of Buildings (E6) Committee/Subcommittee for incorporation into their existing guide (E1998-02, Standard Guide for Assessing Depressurization-Induced Backdrafting and Spillage from Vented Combustion Appliances) and to Title 24 for inclusion as a standard method of test

Benefits:

The project has created new knowledge about risk-based approaches to combustion appliance diagnostics for protecting health and safety, all of which could ultimately be used to update Title 24. Once the results of the project are used in the future to develop new diagnostic tests, the tests will help the CEC and other agencies take a lead on greenhouse gas reducing house retrofits that could be implemented in a cost effective manner, and will serve as a model for code authorities locally and nationally. The outputs of this project are usable by the public and private sectors.

Title:	Energy IQ Action-Oriented Benchmarking				
Agreement Number:	500-10-052	Project Number:	17	Research Stage:	Applied Research
Electricity Funding:	$294,472	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	8/3/2012	End Date:	12/31/2014	Technology Topic:	Benchmarking
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Ratepayers

Description:

This project will build and support Energy IQ, the next generation of energy benchmarking methods to for non-residential buildings. EnergyIQ , a free public-facing user interface, benchmarks energy use, costs, and features for an array of building types and provides a carbon-emissions calculation for the energy consumed in the building, an important part of any businesses' overall "carbon footprint". The additional benchmarking recommendations fundamentally improve on simplified benchmarking processes and help lay the groundwork for investment-grade audits and professional engineering calculations.

Objectives:

The objective was to upgrade EnergyIQ to allow the program to gain users and long-term support from alternative sponsors. The following features were added to EnergyIQ as a result of this project:

Interoperability: Users can now import into EnergyIQ their building data previously entered into the ENERGY STAR Portfolio Manager. This interoperability removes a large barrier for those already using Portfolio Manager to deepen their assessments by graduating to EnergyIQ.

Improved peer-group definitions and filtering: New peer group choices are now available, including comparisons against other users of EnergyIQ or the users' own portfolios. The peer group composition can now be further refined, e.g., filtered by hours of occupancy or efficiency rating level or possession of an Energy Star rating, making peer group selections more relevant.

More metrics and features: New metrics allow for more informative benchmarking (e.g., energy use per employee or hotel bed rather than energy use per unit floor area. Added building characteristics enable users to identify more relevant upgrade recommendations.

Extended recommendations: Recommendations for non-California buildings have been added in recognition of the fact that those assessing California buildings whose responsibilities extend to buildings in other states will not be inclined to utilize EnergyIQ if it cannot be applied to their entire portfolio.

Improved Usability and Documentation : Many refinements were made to the user interface, and extensive documentation (including a User Guide and improved tooltips) was added. API documentation was considerably improved in order to foster technology transfer.

Infrastructure: The entire system has been moved to a cloud-based platform, significantly improving performance and up-time.

Benefits:

Almost 1,300 registered users have collectively entered 900 buildings representing 130 million square feet of floor area. The EnergyIQ website had been visited over 45,000 times (a four-fold increase since the close of Phase II) by nearly 25,000 individuals, viewing over 150,000 pages of information. The EnergyIQ Action-Oriented Benchmarking tool has benefitted California ratepayers by pointing out cost-effective ways to reduce waste in existing buildings. Reducing this costly waste will free-up funding for tangible benefits for ratepayers and improve the California economy and environments. A separate California Energy Commission project—the Small and Medium Building (SMB) Efficiency Toolkit—also integrates EnergyIQ API for guiding users towards efficiency opportunities. This integration is done by benchmarking a building against its peers as the first step in the SMB assessment. Quantified benefits are not available.

Title:	More Efficient Residential Heating/Cooling by Airflow Instrument Standards				
Agreement Number:	500-10-052	Project Number:	19	Research Stage:	Applied Research
Electricity Funding:	$196,315	Match Funding:	$0	Natural Gas Funding:	
Start Date:	8/3/2012	End Date:	12/31/2014	Technology Topic:	HVAC
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Ratepayers

Description:

This study would develop a test procedure based on laboratory testing of a range of flow hoods combined with experience and knowledge gained from developing similar equipment performance testing standards. The focus would be on providing test procedures for reference by California standards, however, similar projects funded by the USDOE will allow outreach to form the basis of national standards through organizations such as American Society of Testing and Materials or American Society of Heating, Refrigerating and Air-conditioning Engineers and will provide support to the development of the California standard.

Objectives:

Improve the measurement of air flow at return grilles in residential HVAC Systems

Benefits:

Energy Commission- Recommendations for changes in allowable test methods for California Building Energy Efficiency Codes/Standards (Title 24).
California contractors-Improved methods to ensure quality installations that ensure correct equipment performance and increase reliability and durability of residential HVAC installations.
California ratepayers:
1. Improved compliance with Title 24 ensuring that homes perform the way California home owners expect.
2.Heating and cooling equipment will operate as intended, ensuring that energy and financial savings from high efficiency equipment are actually achieved.
3. Improved comfort through having verified HVAC air flows to match design specifications, and
4. Improved heating and cooling equipment longevity.

Title:	California Plug Load Research Center				
Agreement Number:	500-10-065	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,000,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	7/1/2011	End Date:	12/31/2014	Technology Topic:	Whole Building
Award Recipient:	UC Irvine			End-Market:	Ratepayers

Description:

This project funds research in the following areas:
Plug Load research to support Title 20, appliance efficiency standards.
(2) Set top boxes - the research will develop energy reduction strategies that can reduce active and lower power energy levels.
Computer enabling rates - the research focuses on understanding energy related behavior for users of personal computers including reasons for modifying default energy settings. This is collectively referred to as enabling rates. The research on personal computers may support future development of a Title 20 standard.
(4) Plug load energy consumption and information display for user awareness.

Objectives:

1. Improve Efficiency of Set Top Box
2. Computer Enabling Study
3. Computer Display
4. Market Outreach

Benefits:

Reduced energy and demand for consumer electronics, such as set top boxes and computers.

Title:	Biogas Fueled HCCI Generation for Combined Heat and Power Systems				
Agreement Number:	PIR-09-014	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$580,706	Match Funding:	$273,689	Natural Gas Funding:	$0
Start Date:	4/12/2010	End Date:	4/30/2014	Technology Topic:	Biomass/ Biogas
Award Recipient:	Makel Engineering, Inc.			End-Market:	Ratepayers

Description:

The proposed project will integrate three operating principles. 1) Combined heat and power (CHP) generation, 2) Homogenous Charge Compression Ignition (HCCI) engine technology, and 3) utilization of biogas. HCCI is a relatively new engine technology but has potential to lower emissions of Nitrogen Oxides (NOx) and other pollutants while maintaining the high level of efficiency typical of modern direct injection (DI) diesel engines. HCCI engine technology provides a low risk path to high efficiency, low emissions and low cost power generation, and a suitable alternative capable of supporting California's increased energy and reduced emission's necessities.

Objectives:

1. Capital Costs - ($/kWe)<1500
2. Achieve high total combined energy conversion efficiency
3. Achieve CHP efficiency of 60%, in terms of useful energy out/HHV of fuel energy in (100% load)
4. Achieve emissions lower than 0.07 lb/MWehr NOx, 0.10 lb/MWehr CO, and 0.02 lb/MWehr VOCx (ARB 2007)
5. Demonstrate flexibility to operate with variable biogas composition
6. Operate at an active dairy during a 12-14 month period, including a minimum of 400 hours of continuous operation.

Benefits:

A. Improving air quality
-Emissions levels that do not require SCR cleanup
-Prevents GHG emissions to the atmosphere by destroying methane in biogas
-Prevents smog formation by destroying ROGs and reducing NOx emissions
B. Reducing operational costs
-Offsetting the cost of electricity for the end users
-Increase revenue for end user from electricity sales
-CHP mode reduces cost for water heating
C. Reduces regulatory penalties
D. Improving site quality (Dairies, for example)
-Odor and fly reduction
-Improved soil nutrient management.
-Digested solids are pathogen free and can be sold for animal bedding or compost
-Effluent liquid can serve as crop fertilizer, reducing need for inorganic fertilizers

Title:	Integrated Solar PV, Advanced Compressed Air Energy Storage, and Microgrid Demonstration Project				
Agreement Number:	PIR-12-004	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,749,000	Match Funding:	$1,243,570	Natural Gas Funding:	$0
Start Date:	6/19/2013	End Date:	3/31/2015	Technology Topic:	Solar PV
Award Recipient:	Foresight Renewable Solutions			End-Market:	Ratepayers

Description:

This project will demonstrate the cost-efficient integration of high penetrations of renewable energy within a given community using locally-available renewable energy resources while increasing the energy security of the community. The community for this project, the Mobile Utilities Support and Equipment Facility located at Naval Base Ventura County, will deploy 150 kW of solar photovoltaic into a community-based microgrid that will include extant diesel back-up generation, energy storage, and mission-critical and routine operational loads. The storage options deployed will include a 100 kW/1000 kW-hr vanadium redox flow battery funded by Energy Commission in addition to traditional lead-acid deep cycle batteries provided by the Navy.

Objectives:

Design, develop, and deploy an innovative hybrid project that integrates 150 kilowatts (kW) of solar PV and a modular 100 kW/1000 kW-hr flow battery energy storage system with a microgrid serving the a community at Naval Base Ventura County

2. Measure, analyze, and document the capital and operating costs of the hybrid project

Verify round-trip efficiency of the vanadium-redox flow battery system of 75 percent or more while supporting the microgrid in both grid-connected and islanded modes

Quantify various operational parameters in terms of power quality (voltage support, and frequency regulation), response time, and operational availability and runtime achievable in island mode

Demonstrate and quantify cost savings to the MUSE facility and NBVC through displacement of utility electrical supply via renewable energy deployment, BESS-enabled load shifting, and peak shaving

Benefits:

One of the primary drawbacks of solar PV is that it is an intermittent resource that does not follow load during daylight hours when it is generating, and does not generate at all after dark. Successfully integrating PV into a microgrid that includes energy storage will enable a community to better match its generation to load by managing loads and by using storage to add or remove electricity to the microgrid to balance load as needed. This includes the ability to store excess electricity generation by day and shift to nighttime hours. Similarly, the ability of flow batteries to store electric power indefinitely affords the community the option of using solar energy as emergency back-up generation, offsetting the use of fossil fuels for that purpose. Energy costs are reduced via reduced consumption of grid electricity, especially during periods of high electricity prices, and via reduced demand charges achieved through peak shaving. Power quality will be improved by the rapid response of the microgrid to changing generation and loads to maintain voltage, frequency, waveform and other quality parameters. Increased reliance on solar will reduce the consumption of fossil fuels and the emission of priority pollutants and greenhouse gases produced thereto.

Title:	ZNE Demonstration- Integration of Dynamic Daylighting and Passive Cooling/Heating for High Return on Investment				
Agreement Number:	PIR-12-024	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,542,233	Match Funding:	$1,553,326	Natural Gas Funding:	$0
Start Date:	6/28/2013	End Date:	1/31/2016	Technology Topic:	Whole Building
Award Recipient:	View, Inc.			End-Market:	Ratepayers

Description:

This project will design, construct, and demonstrate an affordable and broadly replicable design approach for renovating commercial buildings using low-cost dynamic windows for dynamic solar heating, downsizing HVAC space heating needs due to solar heating, and building controls.

Objectives:

Reduce cooling energy by 3 times at a heating, ventilation and air conditioning (HVAC) capital cost that is 5 times lower than required by Title 24 regulations

2. Reduce lighting energy by 3 times, at a lighting installed cost that is 1.5 times lower than required by Title 24

3. Reduce heating energy by 7 times, at an HVAC capital cost that is 5 times lower than required by Title 24

Generate sufficient incremental net-operating income to provide a positive cash flow after servicing debt equal to the total incremental renovation costs over Title 24

5. Has an incremental ROI greater than the market rate on comparable non-sustainable construction (7.5%)

Benefits:

This project demonstration hopes to reduce the financial risk of implementing an unproven approach for the building owner and enables the owner to justify providing significant match funding (>100%). This allows the project to move forward and provides strong leverage for California ratepayers. The project allows the recipient to extensively document the designs, practices, savings and efficiencies of this approach, and publicize the results to the construction, banking, and public policy communities, driving awareness, catalyzing replication and accelerating benefits to California ratepayers.

This project will alter the landscape of future sustainable construction by making ZNE construction a compelling investment opportunity, and eliminates barriers to adoption. This project approach will accelerate adoption across the state, enabling California to not only meet policy goals for ZNE buildings, but to meet them on an accelerated and unsubsidized basis.

Title:	Demonstrating Scalable Very Energy Efficient Retrofits for Low Income, Multifamily Housing				
Agreement Number:	PIR-12-025	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,351,283	Match Funding:	$1,112,800	Natural Gas Funding:	$0
Start Date:	6/30/2013	End Date:	3/31/2016	Technology Topic:	Whole Building
Award Recipient:	Electric Power Research Institute			End-Market:	Ratepayers

Description:

This project will develop cost-effective, replicable packages of energy-efficiency measures (EEMs) that can be used for deep energy efficiency retrofits of low-income multifamily properties. These packages will be installed and demonstrated in 30 apartment units at the Beachwood multifamily complex in Lancaster, CA owned by project partner LINC.

Objectives:

Develop practical, replicable very efficient retrofit (VER) packages for low income multifamily housing. This objective will be met by employing the most recent technical advances to improve existing buildings to the 2008 energy efficiency Title 24 standards, and improve the packages as needed to be Zero Net Energy (ZNE) or ZNE-capable.

Research measures, technologies, and building practices to make the VER packages as close as possible to ZNE capable and still practical, cost-effective and replicable.

Demonstrate, measure, and evaluate the VER packages in the targeted community and define the financing requirements of, and barriers to VERs in the low-income multifamily housing industry. This information will provide insightful recommendations to the financing industry for specific financing vehicles needed for widespread replication of the VER packages.

Benefits:

This project developed deep energy saving packages of different magnitudes of energy savings from about 47 percent improvement from baseline conditions to at least meet 2008 Title 24 energy efficiency standards, to nearly 70 percent for zero net energy capable. Assuming the lowest estimated savings of about 47 percent, this project would reduce electricity use by over 150,000 kWh and natural gas use by over 9,000 therms (thus reducing greenhouse gas emissions by over 240,000 pounds). These numbers translate to reducing energy costs by over $32,000 annually for California ratepayers. The benefits of this project could also be extended to creating additional jobs. Retrofits of low income housing projects require on-site labor, estimated to be one full-time, permanent job for every $100,000 invested in a retrofit, and a corresponding 1.5 jobs off-site. Using these estimates, the LINC housing retrofits alone would produce an estimated 13 new jobs. Additional jobs could be created if LINC housing replicates these retrofits at their 65 other properties located throughout California.

Title:	Innovative Low-Energy Occupant-Responsive Controls for Heating, Ventilation and Air Conditioning Systems				
Agreement Number:	PIR-12-026	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,629,399	Match Funding:	$192,500	Natural Gas Funding:	$0
Start Date:	6/30/2013	End Date:	3/31/2016	Technology Topic:	Whole Building
Award Recipient:	Regents of the University of California/California Institute for Energy and Environment			End-Market:	Ratepayers

Description:

This project has the goal of optimizing control of building heating, ventilating, and air conditioning (HVAC) systems for energy efficiency in conjunction with the use of occupant–based comfort technology innovations. This project will build on preliminary efforts to demonstrate occupant comfort, control, and information systems. This project will create and demonstrate new products and HVAC control & operation practices, and perform the tasks leading to having them adopted in standards, codes, and common practice.

Objectives:

Demonstrate and bring to the market new low-energy, localized personal comfort systems (PCS)
2. Develop methods of test for certifying the efficiency of PCS
3. Develop and demonstrate innovative improvements to VAV control systems
4. Use open-source information technology software for implementing actuation control logic across a full range of DDC systems
5. Implement the results in Standards and Codes (e.g., Title 24, Title 20, ASHRAE 90.1, ASHRAE 55, etc.)
6. Perform technology transfer activities to encourage standards' provisions to be adopted in common practice
Demonstrate and bring to the market new low-energy, localized Personal Comfort Systems (PCSs), and develop methods for certifying their efficiency

Benefits:

This project will lead to the development of a new control paradigm based on enlarging the roles of occupants, operators, and automation in control of buildings. This paradigm applies equally to existing buildings as well as new designs, and includes innovative personal comfort technologies, control improvements, and web-based information technology. These new integrated control strategies have the potential to dramatically improve traditional levels of energy efficiency, increase occupant satisfaction and thermal comfort, and increase the flexibility and useful life of the conditioning systems.

Title:	Codes and Standards Quality Demonstration Program				
Agreement Number:	PIR-12-027	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,167,103	Match Funding:	$121,600	Natural Gas Funding:	$0
Start Date:	7/12/2013	End Date:	3/31/2016	Technology Topic:	Benchmarking
Award Recipient:	The Regents of the University of California			End-Market:	Policymakers/ Regulators

Description:

The goal of this Agreement is to develop a detailed demonstration and assessment program for Energy Commission sponsored and other related building efficiency technologies. The Codes and Standards Enhancement Quality Demonstration project (CASE-QDP) will deliver a complete, robust data set on key energy-efficient technologies and inform and affect future California codes and standards (C&S) activities.

Objectives:

1. Develop a CASE-QDP Program Manual in collaboration with partners and PAC
2. Demonstrate the validity and success of the program framework through multiple technology demonstrations
3. Conduct pre and post retrofit assessments of each demonstrated technology according to the Program Manual framework
4. Deliver energy, market, and economic analyses to CEC and other stakeholders for use in C&S activities
5. Refine the Program manual based on demonstrations and lessons learned

Benefits:

Past research has contributed to both the buildings (Title 24, part 6) and appliance (Title 20) energy efficiency standards associated with lighting, building envelope, HVAC, hot water heating and plug loads. Collectively, the Commission's research contributions are estimated to save Californians over $1 billion annually in reduced energy costs once the measures are implemented.

Title:	Advanced Envelope Systems for Factory Built Homes				
Agreement Number:	PIR-12-028	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,433,568	Match Funding:	$299,781	Natural Gas Funding:	$0
Start Date:	6/30/2013	End Date:	3/31/2016	Technology Topic:	Whole Building
Award Recipient:	The Levy Partnership, Inc.			End-Market:	Residential

Description:

Develop new and innovative methods for building roof and wall systems that dramatically reduce energy use in factory built homes and take steps to transition the market in California to the new methods.

Objectives:

1. Develop roof and wall panel
2. Have an annualized energy cost markedly lower than the current construction methods

Benefits:

Develop for factory use roof and wall designs that use continuous exterior insulation, such as structural composite panels. R value will increase in walls to R26 which will reduce energy and demand. Projected savings are 1,500 kWh and 140 therms per year per building.

Title:	Small and Medium Building Efficiency Toolkit and Community Demonstration Program				
Agreement Number:	PIR-12-031	Project Number:	1	Research Stage:	Technology Development
Electricity Funding:	$2,000,000	Match Funding:	$254,790	Natural Gas Funding:	$0
Start Date:	6/30/2013	End Date:	3/31/2016	Technology Topic:	Whole Building
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Ratepayers

Description:

This proposed research will develop a retrofit energy toolkit for small and medium buildings (SMB) and demonstrate the Toolkit's capabilities on three to four building test sites. The project will also obtain input from stakeholders on retrofit packages, compile utility smart-meter data to develop the load shape analysis module, determine the indoor environmental quality effects on retrofitted small office and retail buildings, and develop a comprehensive web-based retrofit tool for business owners and energy professionals.

The Toolkit will help small businesses better understand the choices available to reduce their energy bills given their existing building equipment, operating patterns, natural gas and electric systems, and energy consumption load shapes. It will help property and business owners produce custom implementation plans that integrate building performance technology packages and will provide building-specific suggestions for immediate action. These actions will include low-cost or no-cost changes to control systems and operations, as well as retrofit scenarios and prioritized actions for efficiency improvements, from simple to deep retrofit options.

Objectives:

Develop streamlined data collection and performance measurement systems that maximize existing data and approaches used in this sector

Partner with California businesses, local governments, and IOUs to develop, test, and demonstrate the SMB Toolkit to validate a robust, practical and effective SMB retrofit assessment method

Develop an IEQ information and a ventilation measurement system for rooftop HVAC, to ensure that ventilation rates are adequate but not excessive

Develop a rapid web-based retrofit assessment tool based on load shapes, benchmarking, and a pre-simulated database of retrofit measure energy savings results for small and medium office and retail buildings.

5. Define the functional requirements for conducting SMB retrofit assessments

6. Develop the SMB Toolkit web services APIs, based on the identified functional requirements, that can deliver SMB retrofit energy savings calculations for a wide range of web-based applications

7. Prototype a freely available web-based retrofit analysis tool using the developed APIs to evaluate both individual and package of retrofit measures

Benefits:

The SMB Toolkit will be used by engineers, energy consultants, facility, property managers and building and business owners to systematically determine and rank energy retrofit opportunities. All existing small and medium size buildings in California could achieve in electricity savings, non-coincident peak demand savings, thereby reducing strain on the electricity grid, natural gas savings, energy-related cost savings, and reducing emissions.

Title:	Tools and Materials for Zero Net Energy California Buildings				
Agreement Number:	PIR-12-032	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,335,074	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/30/2013	End Date:	3/31/2016	Technology Topic:	Modeling
Award Recipient:	The Regents of the University of California			End-Market:	Ratepayers

Description:

Phase change materials (PCMs) are energy storage materials that can store thermal energy in the form of latent heat when subjected to temperatures in excess of their melting point by undergoing a phase transition from solid to liquid state. Reversibly, PCMs can release the thermal energy previously stored when the system temperature drops below their melting point. The project will result in a building envelope, which is able to better manage thermal demands by buffering the internal building thermal conditions against diurnal and seasonal variations. The outcomes will enable marked reductions in building energy use, and (time)-shift peak load periods to off-peak hours, thus also enhancing electrical grid stability.

Objectives:

1. A New Kind of Phase Change Envelope for Zero Net Energy Buildings
2. Software Tools for designing Zero Net Energy Buildings
3. Data Collection and Analysis
4. Technology Transfer Activities
5. Production Readiness Plan

Benefits:

This project will create information on the performance of a new kind of high mass phase change construction material, and will develop new and expanded software tools to help Californians design more energy efficient buildings.

Title:	Energy and Indoor Environmental Quality (IEQ) Retrofits In Low-Income Apartments				
Agreement Number:	500-09-022	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,750,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	2/1/2010	End Date:	1/31/2014	Technology Topic:	Whole Building
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Ratepayers

Description:

The goals of this project were to develop methods for retrofitting low income apartments and to quantify the resulting energy and indoor environmental quality (IEQ) benefits. Energy efficiency retrofits in apartments may improve or degrade IEQ conditions that affect comfort and health; however, current practices largely neglect the effects of retrofits on IEQ. This project developed, tested, and demonstrated a protocol for selecting packages of retrofits that maximize overall energy plus indoor environmental quality benefits in apartments serving low income residents.

Objectives:

Advance knowledge and tools for apartment retrofits to save energy and improve IEQ
Advance understanding of the benefits of retrofits intended to reduce energy consumption and improve indoor environmental quality (IEQ) in low income apartments
3. Provide a demonstration of the methods for and benefits of such retrofits
4. Develop and document retrofit selection protocols

Benefits:

Energy efficiency retrofits in apartments may improve or degrade indoor environmental quality (IEQ) conditions that affect comfort and health; however, current practices largely neglect the effects of retrofits on IEQ. This project developed, tested, and demonstrated a protocol for selecting packages of retrofits that maximize overall energy plus indoor environmental quality benefits in apartments serving low income residents. The protocol and project findings will help public agencies and private sector stakeholders make better retrofit-selection decisions. These finding may be used by organizations such as the California Energy Commission, U.S. Department of Housing and Urban Development, apartment owners and management companies and energy retrofit providers.

Title:	Analysis of Forest Biomass Removal on Biodiversity				
Agreement Number:	500-09-031	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,149,361	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/1/2010	End Date:	3/31/2015	Technology Topic:	Forestry
Award Recipient:	USDA Forest Service, Sierra Nevada Research Center, Pacific Southwest			End-Market:	Energy Suppliers

Description:

Bioenergy systems in forested areas rely on biomass residue harvested from the ground. This study is determining the effects of different types and impacts of biomass harvest, also known as fuel reduction treatment, in conifer forests on the vertebrate biological diversity. In addition, this study evaluates fuel reduction treatments to enhance the ability to predict the effects of treatments at site and landscape scales.

Objectives:

Determine stand-scale responses of songbirds and small mammals to different intensities of fuels reduction treatments

Compare responses of songbirds and small mammals to other forest management objectives, such as reducing surface and ladder fuels and the risk of crown fire

Determine how different landscape management scenarios would affect the proportion of the landscape that provides suitable habitat for various species of songbirds and small mammals that represent different life history characteristics and habitat needs

Benefits:

This project will provide information that will help minimize environmental risks of severe wildfire in California while encouraging the production of biofuels.

Title:	Air Quality Implications of Electrification and Renewable Energy Options				
Agreement Number:	500-09-040	Project Number:	1	Research Stage:	Policy/Regulation Support
Electricity Funding:	$835,711	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/7/2010	End Date:	3/31/2015	Technology Topic:	Criteria Pollution Emissions
Award Recipient:	Advanced Power and Energy Program - UC Irvine			End-Market:	Policymakers/ Regulators

Description:

The goal of this project is to: 1) identify and analyze renewable power implementation scenarios with enabling technologies and demand response strategies that can maintain system reliability and substantially improve air quality and reduce greenhouse gas emissions in California and 2) explore reducing emissions of criteria pollutants and greenhouse gases (GHG) to meet future health-based federal air quality standards and GHG targets in California through increased electrification. This project is identifying and analyzing renewable power implementation scenarios with enabling technologies and demand response strategies that can maintain system reliability and optimize the impact on air quality and greenhouse gas emissions in California. The project is also identifying and analyzing electrification scenarios that: 1) reduce emissions of GHGs to meet California targets and 2) result in criteria pollutant levels in the SCAQMD and SJVAPCD that meet the federal Clean Air Act standards by 2023 and 2032.

Objectives:

Review existing relevant literature and previous studies
Organize and conduct stakeholder interviews and a workshop focused on coordination with current and previous efforts including at the California Energy Commission (Energy Commission) and National Renewable Energy Laboratory (NREL)
3. Develop future more renewable grid implementation scenarios (detailed electric sector modeling)
4. Develop electrification scenarios
5. Spatially and temporally allocate emissions from each scenario
6. Simulate air quality impacts of each scenario with a detailed atmospheric chemistry and transport model
7. Develop life cycle GHG emissions inventories for each scenario

Benefits:

Results of this project will provide decision makers and regulations with rigorous and scientifically sound determination of the air quality impacts of 1) installing and operating renewable power and the required complementary resources to meet California RPS goals and 2) implementation of electrification. Electrification is seen as one of the key components to both improving air quality in the South Coast and San Joaquin Valley Air Management Districts and meeting state GHG reduction goals. The South Coast has made it a priority to promote electrification in both stationary and mobile applications.

Title:	Visualizing Climate Change Risk and Adaptation Options for California: CalAdapt				
Agreement Number:	500-10-007	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$549,975	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	8/16/2010	End Date:	2/25/2014	Technology Topic:	Other
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Energy Suppliers

Description:

One of the major challenges the climate change adaptation community is the lack of readily accessible visualization tools to portray the risks posed by climate change. There is a serious bottleneck in delivering relevant information, much of which is spatial in nature, in a manner that fosters use of climate change research results to support climate change adaptation decisions and policies. Recognizing this important gap, California's first Climate Adaptation Strategy (2009) mandated the CEC todevelop Cal-Adapt so that a fully functional website is available to provide visualization of local and regional climate change-related risks. Cal-Adapt was developed to fulfill that mandate.

Objectives:

Specific goals of this project were to: 1) develop a prototype website into a fully functional climate change risk assessment tool; 2) provide climate change data and information to local, regional, and state-level entities via the Cal-Adapt website to inform planning processes; and educate people in California about potential impacts of climate change as well as adaptation options.

Benefits:

Cal-Adapt has played a significant role in helping Californians understand how climate change is projected to impact their state and local areas. It has benefited citizens who are interested to learn more about these challenges, local planners and technicians who must plan for adaptation measures that address climate change, and developers of state policy and guidance as well as scientists who require access to data to fulfill their responsibilities.

Title:	Mapping Habitat Distributions of Desert Rare Plants from Optimized Data				
Agreement Number:	500-10-017	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$580,907	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	10/11/2010	End Date:	9/1/2014	Technology Topic:	Flora
Award Recipient:	The Regents of the University of California, Davis			End-Market:	Energy Suppliers

Description:

This project compiled new, accurate coordinate data for 6,563 specimens of Mojave and Colorado Desert rare plants housed in the Jepson Herbarium at the University of California, Berkeley. Researchers modeled the distribution of species from this database on known locations for use in the DRECP planning process. The researchers also developed a rigorous habitat suitability model based on two analytic methods, including field validation of models, to improve predictions of potential habitat for eight rare plant species.

Objectives:

Develop an initial target taxa list that will include taxa with potential impacts from solar development and taxa that meet the requirements for species distribution modeling

2. Generate high quality coordinate data for target taxa using locality information maintained in the Consortium of California Herbaria

3. Develop and statistically evaluate a suite of species distribution models for the initial target taxa list

Refine and develop species distribution models for a set of field evaluation target taxa based on assessment of models developed for the initial target taxa list

5. Field test the accuracy of a subset of species distribution models from the evaluation target taxa list

6. Generate a final report of model predictions and assessment for the evaluation target taxa list

Benefits:

The data used to develop the models and resulting maps of rare plant distribution are available for public use by state and federal land management agencies, non-governmental organizations, private industry, and academia. Overall, this project is providing both a methodology and an assessment of the accuracy and potential usefulness of habitat suitability models for rare plant conservation and mitigation planning to help minimize the impact of projects in the California desert.

Title:	Use of Habitat Suitability Models and Head-Start Techniques to Minimize Conflicts between Desert Tortoises and Energy Development Projects in the Mojave Desert				
Agreement Number:	500-10-020	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$238,310	Match Funding:	$46,000	Natural Gas Funding:	$0
Start Date:	11/1/2010	End Date:	3/31/2015	Technology Topic:	Fauna
Award Recipient:	The Regents of the University of California, Davis			End-Market:	Policymakers/ Regulators

Description:

The objectives of this research are to produce a habitat suitability model for desert tortoises in the Mojave Desert region of California that includes new data on the habitat use of juvenile desert tortoises studied and to determine the effectiveness of head-starting as an augmentation tool for reversing declines of the desert tortoise, caused in part by the expansion of renewable energy development within their geographic range. The results can help improve mitigation actions required of renewable energy projects and in siting new development.

Objectives:

Produce a habitat suitability model for desert tortoises in the Mojave Desert region of California that includes new data on the habitat use of juvenile desert tortoises studied under the terms of this agreement.
Determine the effectiveness of head-starting as an augmentation tool for reversing declines of the desert tortoise, including quantifying the increase in growth or survival that arises from captive head-starting as compared to natural growth and survival of direct released animals at hatching.

Benefits:

This research will help meet the goals of maximizing sustainability while minimizing environmental costs. First, the development or enhancement of habitat suitability models that delineate the distribution and habitat use of special-status species can inform sustainable site selection of planned facilities to minimize their impacts on these species or populations. Second, the establishment or refinement of mitigation strategies and protocols can help ensure persistence of special-status species in suitable areas in a manner that may offset negative impacts to local populations due to energy site installations.

Title:	Energy, Air Quality, Water and Climate Change Co-Benefits of Renewable Generation and Fuels Roadmap				
Agreement Number:	500-10-040	Project Number:	1	Research Stage:	Road Mapping
Electricity Funding:	$157,965	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/20/2011	End Date:	6/30/2014	Technology Topic:	Planning
Award Recipient:	Advanced Power and Energy Program - UC Irvine			End-Market:	Policymakers/ Regulators

Description:

The purpose of this project is to develop a roadmap identifying the state of knowledge, research gaps, and recommended research pathways to quantify the air quality benefits/disbenefits of renewable generation and of alternative fuels and the energy and environmental co-benefits of using these resources in California.

Objectives:

1. Conduct research and host a workshop to identify the proven and/or expected performance of alternative energy and fuel technologies
2. Conduct research and host a workshop to identify methods to analyze energy, environmental and climate change co-benefits
Develop a roadmap that identifies the state of knowledge, research gaps, and recommended research pathways to evaluate potential air quality impacts and energy, climate change and water co-benefits of the use of traditional, alternative and renewable fuels in California

Benefits:

California has some of the unhealthiest air in the nation and it is critically important that the use of new fuels does not adversely impact the States air quality and that the co-benefits of these fuels be identified. By understanding the potential impacts of alternative fuels before they are in widespread use, policy makers and regulators can incorporate this knowledge into building an environmentally sound generation portfolio. This foresight may result in less environmental and economic burden through proper planning. A roadmap would help to ensure that the research is geared toward ensuring the finite resource of clean air is incorporated into future generation scenarios.

Title:	The Projected Effects of Climate Change Induced Changes in Vegetation on Future Hydrologic Energy Generation in California				
Agreement Number:	500-10-045	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$600,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/30/2011	End Date:	3/31/2015	Technology Topic:	Climate Change Adaptation
Award Recipient:	UC Santa Barbara			End-Market:	Policymakers/ Regulators

Description:

Relatively little is known about the extent to which feedbacks between fire and invasive species may alter natural fire regimes and long term trends in vegetative cover and hydrologic cycling in California due to climate change. This project was designed to start addressing these issues to improve watershed-scale models for managers of hydroelectric facilities.

Objectives:

Characterize representative watersheds in the Sierra Nevada Mountains and coastal southern California for vegetation analysis and application of eco-hydrology models

Quantify the degree to which fire, invasive species and climate change play a role in vegetation type conversion in these environments

Examine sensitivity of streamflows, nutrient dynamics and hydropower generation to vegetation characteristics and climate variability

Benefits:

The complex feedbacks between fire and invasive species may alter natural fire regimes and long term trends in vegetative cover and hydrologic cycling in California due to climate change. A greater understanding of these issues will improve the ability of water managers to predict the effects of land cover and climate change on the availability of water for hydropower operations. These issues will become more critical as climate change affects both water supplies and occurrence of wildfire.

Title:	Enhancement to the Development of Forest Carbon Inventory and Monitoring Tools Using Remote Sensing				
Agreement Number:	500-10-046	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$400,000	Match Funding:	$165,000	Natural Gas Funding:	$0
Start Date:	6/30/2011	End Date:	6/30/2014	Technology Topic:	GHG Sequestration
Award Recipient:	The Regents of the University of California on behalf of the Berkeley campus			End-Market:	Energy Suppliers

Description:

This project will enhance greenhouse gas emission accounting methods for California by developing methods to account for reduced carbon dioxide uptake and GHG emissions from forest areas affected by dramatic increases in the number of standing dead trees. The researchers will use field inventories of forest characteristics together with satellite remote sensing data to generate maps of biomass and carbon over time, which will be tested against independent estimates from sites across the state.

Objectives:

Design an operational method to repeat estimates of vegetation carbon density for the forest sector in California for 2005 and 2010 that accounts for the carbon stored in standing dead trees
2. Estimate GHG emissions and removals due to catastrophic tree mortality unrelated to wildfire in California for 2005 and 2010
3. Explore operational methods to monitor and track landscape-scale tree mortality in California's forests

Benefits:

This project will benefit regulators at the Air Resources Board by improving the emissions accounting and monitoring methods for managing carbon credits from forest projects. Ratepayers will benefit from more cost-effective inventory methods that maximize environmental benefits of carbon credits. Energy producers will benefit from accurate estimates of the energy potential from forests.

Title:	Hyperlight Low-Cost Solar Thermal Technology				
Agreement Number:	500-10-063	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$1,000,000	Match Funding:	$447,175	Natural Gas Funding:	$0
Start Date:	6/30/2011	End Date:	3/30/2015	Technology Topic:	Solar Thermal
Award Recipient:	Combined Power Cooperative (formerly Advanced Lab Group Cooperative)			End-Market:	Energy Suppliers

Description:

To support the state's in achieving its Renewable Portfolio Standard goals and to address concerns about the effect of large scale solar energy in the California deserts as reflected by the Desert Renewable Energy Conservation Plan (DRECP), the PIER Energy-Related Environmental Program, in conjunction with PIER Renewables, released a request for proposals (RFP) for RD&D aimed at innovative utility-scale solar energy technologies, spatial arrays, and methods of installation/maintenance that result in significantly lowered facility footprint and/or land impact, as well as innovative approaches to reduce the major freshwater consuming aspects of utility-scale solar energy.

Objectives:

1. Increase the size of the HyperlightTM demonstration units
2. Improve system thermal efficiency from 17% to 30%
3. Reduce evaporative water loss to less than 10%
4. Validate predictive cooling model

Benefits:

Hyperlight Technology has even lower land requirements than conventional linear Fresnel technology because it can space the mirrors closer together and is lower cost due to lower cost materials. This allows greater usage of disturbed and developed lands to expand site selection options. Because of the lower cost, smaller projects can be built on small parcels of land. This will increase opportunities to avoid undisturbed habitats and large areas of remote and environmentally sensitive desert lands, as are currently needed for large-scale solar developments.

Title:	Economically and Environmentally Viable Strategies for Conversion of Bioresources to Power				
Agreement Number:	500-11-028	Project Number:	1	Research Stage:	Policy/Regulation Support
Electricity Funding:	$397,236	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Biomass
Award Recipient:	Advanced Power and Energy Program - UC Irvine			End-Market:	Policymakers/ Regulators

Description:

The goal of this project is to quantify the energy and environmental impacts of increased biomass electricity generation, and the generation and utilization of transportation fuels derived from biogas in California with an emphasis on air quality improvement and economic viability. The project will characterize air quality, green house gas, fossil fuel consumption and economic implications of increased biomass and biogas usage for several electricity generation, heat, and transportation fuel strategies. It will also assess the potential implementation of new bioenergy infrastructure to inform preferred uses and strategies for a set of California renewable resources. The analysis will quantify the emissions of criteria pollutants for several biomass and biogas technology supply chain and utilization scenarios. The resulting emissions will be spatially and temporally resolved for and used in air quality modeling to account for atmospheric chemistry and transport to determine the overall air quality impacts of the new biopower infrastructure.

Objectives:

Characterize system implications of increased biomass and biogas usage for several electricity generation, heat generation, and transportation fuel strategies.
2. Evaluate air quality, greenhouse gas, fossil fuel consumption and economic implications.

Benefits:

Results from this study will complement ongoing research and help inform policy makers and industry with respect to further development and direction of biomass and biogas policy and technology alternatives needed to meet energy and environmental goals in California.

Title:	Air Quality Issues Related to Using Biogas from Anaerobic Digestion of Food Waste				
Agreement Number:	500-11-030	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$164,201	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	3/30/2015	Technology Topic:	Biogas
Award Recipient:	CSU Fullerton			End-Market:	Policymakers/ Regulators

Description:

Biogas is the main desirable product from anaerobic digestion of food waste. The quality and quantity of biogas will be affected by many parameters including pH, temperature, food composition, loading rate, mixing condition, reactor design, and retention time. One of the main tasks of this proposed project is to collect biogas data to generate scientific information needed to more accurately estimate emissions from anaerobic digesters.

Objectives:

Develop the scientific information needed to more accurately estimate emissions from anaerobic digesters that use food waste
2. Develop scientific information needed for conditioning/pretreatment of raw biogas
3. Develop the scientific information needed to support the air quality permitting process for this type of anaerobic digester in the future

Benefits:

Meeting air emission requirements is paramount to the successful implementation of any biopower project in California, however scientific information on air quality of biogas from anaerobic digesters treating food waste and the emissions from beneficial uses of this type of biogas is very scarce. This project will provide information that will inform determination of conditioning requirements for this type of biogas for various beneficial uses and for determination of air permitting and discharge requirements for future food waste anaerobic digestion projects.

Title:	Measure of Carbon Balance in California Deserts: Impacts of Widespread Solar Power Generation				
Agreement Number:	500-11-033	Project Number:	2	Research Stage:	Applied Research
Electricity Funding:	$164,879	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Land Use
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Policymakers/Regulators

Description:

This project with UC Riverside is developing measurements and adapting models to measure stored inorganic carbon, organic carbon balances of differing vegetation types, and changing soil temperature, moisture, and atmospheric CO_2 levels to determine if there are particular vegetation types that should be protected from disturbance or others that, from a perspective of carbon balance, are less sensitive.

Objectives:

Measure caliche at various locations using soil pits and ground-penetrating radar. Take samples of caliche, soil, and vegetation from multiple vegetation types, regions, and soil depths to determine the exchange rates of carbon and oxygen from the original deposition.

Utilize a networked environmental observatory to measure C fixation, respiration and allocation. Model organic carbon and calcium carbonate dynamics under varying vegetation, soils and climate conditions.

3. Monitor the fluxes of CO_2, water, and energy of whole ecosystems at a spatial scale of hectares, using eddy covariance.

Benefits:

This project facilitates understanding of the impacts of widespread solar power development and generation on the carbon balance in deserts.

Title:	Development of Innovative Tools to Use Weather Data to Assess and Monitor Impacts of Existing and Future Energy Facilities on Aerial Faunas in California				
Agreement Number:	500-11-033	Project Number:	3	Research Stage:	Applied Research
Electricity Funding:	$165,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Avian Impacts
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Energy Suppliers, Policymakers/Regul

Description:

This project with UC Santa Cruz is developing tools to facilitate identification of the biological hot-spots of migratory and aerial vertebrate activity in terrestrial and off-shore ecosystems through California, in order to determine how existing and future energy facility development will impact sensitive species such as migratory birds and bats.

Objectives:

Develop an analytic tool for automated analysis to identify and quantify aerial bioscatter from current and archived weather radar data for predicting "hot spots" of migratory and local activity of aerial vertebrates in relation to existing and planned energy development.

Utilize DNA-based detection methodology that uses population-specific markers to identify specific migratory bird populations being surveyed.

Benefits:

By facilitating identification of the avian migration corridors, this project will increase the production of wind power in California while mitigating the impacts of turbines on avian species.

Title:	Assessment of Offshore Wind Development Impacts on Marine Ecosystems				
Agreement Number:	500-11-033	Project Number:	4	Research Stage:	Applied Research
Electricity Funding:	$153,017	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Wind (offshore)
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Energy Suppliers, Policymakers/Regulators

Description:

This project with UC Los Angeles is building a tool that can accurately assess offshore wind power while simulating direct atmospheric and ocean impacts and indirect marine ecological impacts of wind farms. This will be used to simulate the effects of upwelling on the nutrient distribution of the ocean, which can be used to predict the effects of wind power on marine health.

Objectives:

Perform present-day and regional coastal climate reconstructions using data from historical climate archives at the lateral boundaries of the outer domains of both the atmospheric and oceanic models.
Perform simulations using models with ocean biogeochemistry without wind farms to obtain baseline data and with wind farms to examine the effects of wind power on the atmosphere and the ocean.
Evaluate the difference in marine biogeochemical quantities between the three simulations to quantify the impact of wind farms on marine ecosystems.

Benefits:

This project will facilitate the development of off-shore wind by assessing the potential environmental impacts on marine species and ecology.

Title:	Evaluation of a Passive Acoustic Monitoring Network for Harbor Porpoises in California				
Agreement Number:	500-11-033	Project Number:	5	Research Stage:	Applied Research
Electricity Funding:	$149,815	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Wind (offshore)
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Energy Suppliers

Description:

This project with San Jose State University is developing and evaluating the feasibility of a passive acoustic monitoring network for the harbor porpoise in California. The network will provide a critical tool for collecting baseline data and monitory impacts of Marine Renewable Energy facilities on this protected species, allowing planners to select sites where impacts to harbor porpoises are minimal.

Objectives:

Collect data to quantify the relationship between acoustic detections and harbor porpoise presence. Use collected data to determine spatial and temporal scales at which changes in harbor porpoise distribution can be detected.
Develop alternate C-POD network designs and perform simulations on alternate C-POD network designs to assess the capabilities patterns of the harbor porpoise using ten years of past fine0scale porpoise distribution data.
3. Simulate scenarios of increasing and decreasing true porpoise abundance versus changes in distribution using aerial survey data. Apply model scenarios to potential network configurations around candidate Marine Renewable Energy sites to determine most appropriate special arrangement for effective harbor porpoise monitoring.

Benefits:

This project will facilitate the development of Marine Renewable Energy (off-shore wind) by assessing the potential environmental impacts on marine species and ecology.

Title:	Development of an Environmental Impact Assessment Tool for Wave Energy				
Agreement Number:	500-11-033	Project Number:	6	Research Stage:	Applied Research
Electricity Funding:	$165,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Wave Power
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Energy Suppliers

Description:

This project with San Diego State University is assessing the environmental impact of Wave Energy Conversion, focusing on the degradation to the shoreline and the potential of waves dislodging wave energy converters from their moorings, causing injury to people and damage to property.

Objectives:

Identify the status of wave energy conversion technologies and identify likely technologies that will be adopted for WECs in California.

Develop statistical weather data for input to the wave energy model simulation and build a simulation model for statistical wave inputs to quantify the magnitude of energy.

Analyze 30 years of wave parameter statistics from wave buoy data off the California coast; assess for the presence of waves with significant wave heights greater than 12 meters 4-5 miles off shore; simulate storms that cause large wave heights 4-5 miles off shore; and develop tools for large wave event probability and accurate 72-hour forecasts.

Benefits:

This project will facilitate the development of Marine Renewable Energy (wave energy conversion) by assessing the potential environmental impacts on marine species and ecology.

Title:	Development of a Modeling Tool to Assess and Mitigate the Effects of Small Hydropower on Stream Fishes in a Changing California Climate				
Agreement Number:	500-11-033	Project Number:	7	Research Stage:	Applied Research
Electricity Funding:	$0	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Fish Passage
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Policymakers/ Regulators

Description:

This project with UC Davis is developing a fish habitat suitability model that uses an integrated modeling framework consisting of a watershed hydrology management model and a fish habitat suitability model to assess the impacts of small hydropower plants on freshwater fish populations in California.

Objectives:

Plan and conduct meetings with stakeholders to determine small hydropower operations and fish population and habitat goals

Perform a literature review to determine life-stage and run-specific functional relationships and critical thresholds for each freshwater site to be included in the model, e.g. mortality rates as a function of water temperature, egg survival and development rates, and critical temperature and flow requirements for volitional migration for adults

Develop a model for integration into the Water Evaluation and Planning (WEAP) framework. Input from WEAP will be temperature and flow

4. Calibrate model using historic data

5. Conduct a sensitivity analysis (feasibility test) to determine the robustness of model results

Conduct site visits to representative small hydropower facilities. Collect detailed water temperature data upstream and downstream of a representative small hydropower facility for use in model development and calibration

7. Plan and conduct a workshop near end of project to present the model to stakeholders

Benefits:

This project will lay the groundwork for future efforts to assess trade-offs between water use providing freshwater habitat for native fish populations, and the cost-efficient provision of water to small hydropower installations.

Title:	Assessment of the Potential Environmental Impacts of Alternative Energy Scenarios for California				
Agreement Number:	500-11-033	Project Number:	8	Research Stage:	Applied Research
Electricity Funding:	$0	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Other
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Policymakers/ Regulators

Description:

This project with UC Berkeley is developing a tool to identify potential environmental issues associated with different energy development scenarios, including land-use impacts, air-quality impacts (e.g., fossil fuel and bioenergy impacts), and climate-change impacts.

Objectives:

Develop a methodology to estimate the land use implications of different energy technologies
2. Estimate the potential land-use impacts of future energy scenarios in Califonria
3. Estimate the emissions of air pollutants that would be associated with the different scenarios
Examine current and potential water impacts of energy generation scenarios and investigate mitigation options such as increased water use efficiency, multiple-use cycles, and reclaimed water avenues
Examine the potential location of biomass energy resources and estimate the associated demands of water, fertilizer, and herbicide and land resource impacts
Develop methods that can be used with the model to explore the effects of climate change on renewable sources of energy such as changes in hydropower availability, wind resources, and biomass resources

Benefits:

A key factor in evaluating alternative future energy system scenarios intended to achieve significant greenhouse gas reductions is the associated environmental benefits and impacts of those scenarios. This project's evaluation is critical to ensure that the goal of reducing greenhouse gasses is achieved, and achieved in manner that does not exacerbate unintended environmental consequences.

Title:	Aerial Line Transect Surveys for Golden Eagles within the Desert Renewable Energy Conservation Plan Area				
Agreement Number:	500-12-005	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$200,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/14/2013	End Date:	3/31/2015	Technology Topic:	Avian Impacts
Award Recipient:	Humboldt State University Sponsored Programs Foundation			End-Market:	Policymakers/Regulators

Description:

This project estimates the abundance and age structure of golden eagles within the Desert Renewable Energy Conservation Plan area and southwestern Imperial County during the early breeding season and during the post-fledging period. The surveys provide unbiased estimates of the size of the golden eagles population within the study area and provide a baseline for detecting trends in the population over time.

Objectives:

Establish unbiased aerial line-transect surveys across a study area of sufficient length to obtain accurate estimates of the golden eagle population.
2. Estimate the survey effort needed to obtain accurate estimates of the golden eagle population in the study area on future surveys.
Estimate the proportion of golden eagles detected within the two kilometer-wide line transects during the early breeding and post-fledging surveys.
Compare the accuracy of estimates using the previously established protocol for golden eagle aerial surveys and a Bayesian approach that uses information from previous surveys and from those conducted in the DRECP area.

Benefits:

This project will provide a greater understanding of golden eagle populations within the Desert Renewable Energy Conservation Plan (DRECP) area, facilitating effective balance of eagle conservation and renewable energy development within the DRECP.

Title:	Research to Improve Golden Eagle Management in the Desert Renewable Energy Conservation Planning Area				
Agreement Number:	500-12-007	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$314,000	Match Funding:	$14,700	Natural Gas Funding:	$0
Start Date:	6/21/2013	End Date:	3/31/2015	Technology Topic:	Avian Impacts
Award Recipient:	US Geological Survey			End-Market:	Policymakers/Regulators

Description:

This project researches Golden Eagle population dynamics in the desert and the potential impacts of wind and other energy development on that population in order to help achieve Desert Renewable Energy Conservation Plan goals.

Objectives:

Develop monitoring guidelines to ensure future surveys and monitoring efforts provide a statistically robust methodology to assess Golden Eagle population dynamics.

Conduct surveys to identify Golden Eagle nesting sites and to assess prey availability and the habitat necessary for the prey to determine effects of renewable energy development on the Golden Eagle.

Benefits:

This project will provide a greater understanding of golden eagle populations within the Desert Renewable Energy Conservation Plan, facilitating effective balance of eagle conservation and renewable energy development within the DRECP.

Title:	Improving the Accuracy and Cost-effectiveness of Pre-Construction and Operations Monitoring Efforts for Bats and Birds at Wind Energy Facilities in California				
Agreement Number:	PIR-08-024	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$550,948	Match Funding:	$200,389	Natural Gas Funding:	$0
Start Date:	7/1/2009	End Date:	3/31/2014	Technology Topic:	Avian Impacts
Award Recipient:	US Forest Service Pacific Southwest Research Station			End-Market:	Policymakers/Regulators

Description:

This research expanded upon earlier PIER-sponsored research to resolve methodological issues and quantify environmental conditions that predict activity and fatality rates of bats and birds at wind farms in California. Improving these methods not only helps to protect wildlife in the state, but providing methods that allow accurate estimates of activity and fatality to be made cost-effectively facilitate the growth of wind energy in the state.

Objectives:

Model the environmental conditions that predict activity and fatality levels of bats and nocturnally-active birds and evaluate the effectiveness of acoustic flight call monitors as an index of activity by birds that migrate at night.

Recommend cost-effective allocation of survey efforts and sampling strategies to estimate bird and bat activity at wind energy facilities in California.

Benefits:

By facilitating identification of the avian migration corridors, this project will increase the production of wind power in California while mitigating the impacts of turbines on avian species.

Title:	Population Viability and Restoration Potential for Rare Plants Near Solar Installations				
Agreement Number:	PIR-10-047	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$753,100	Match Funding:	$149,885	Natural Gas Funding:	$0
Start Date:	11/22/2010	End Date:	3/23/2015	Technology Topic:	Flora
Award Recipient:	BMP Ecosciences			End-Market:	Energy Suppliers

Description:

The overarching goal of this project is to provide Energy Commission and other agency staff, renewable energy developers and other stakeholders information on the population viability of a number of special status plant species likely to be impacted by utility scale solar energy development in the Mojave and Colorado Deserts.

Objectives:

Identify a representative suite of six to eight target plant taxa of special status or conservation concern (including listed taxa if possible)

2. Identify and characterize two to three occupied natural study populations of each target taxon

Collect four years of field demographic data to parameterize population viability models for each target taxon. Complete demographic data collection will include experiments to determine rates of seed dormancy, a seldom-studied yet essential model component

Develop and interpret PVA models for each of the target taxa, including estimation of extinction threshold subpopulation size and its associated expressions as generated by a sensitivity analysis that links population viability to levels of project impact

Benefits:

This agreement will provide information on population viability for rare plant taxa that may be impacted by utility scale solar energy development in the Mojave and Sonoran Deserts of California. Analysis and interpretation of this data will inform the development of management strategies, including restoration and mitigation strategies that will help streamline the siting process.

Title:	Effect of Utility-Scale Solar Development and Operation on Desert Kit Foxes				
Agreement Number:	PIR-11-012	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$606,257	Match Funding:	$29,710	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	3/1/2015	Technology Topic:	Fauna
Award Recipient:	Randel Wildlife Consulting, Inc.			End-Market:	Energy Suppliers

Description:

This research will quantify the effects utility-scale solar facility construction and operations have on the home ranges and movements of desert kit foxes and provide a scientific baseline for guidance in assessing, mitigating, and evaluating utility-scale solar development impacts on the desert kit fox. This research will help lessen barriers and delays in the renewable energy facility siting and permitting process.

Objectives:

Quantify the effects of utility-scale solar facility construction and operations have on the home range and movements of desert kit foxes

2. Provide a scientific baseline for developing guidelines to evaluate utility-scale solar development impacts on the desert kit fox

Benefits:

This research will help lessen barriers and delays in the renewable energy facility siting and permitting process.

Title:	Improving Environmental Decision Support for Proposed Solar Energy Projects Relative to Mojave Desert Tortoise				
Agreement Number:	PIR-11-013	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$563,776	Match Funding:	$62,970	Natural Gas Funding:	$0
Start Date:	6/26/2012	End Date:	3/30/2015	Technology Topic:	Fauna
Award Recipient:	Redlands Institute, University of Redlands			End-Market:	Energy Suppliers

Description:

This research will reduce environmental conflict over solar energy development projects by providing scientific information and decision support technology to better assess the potential threats, impacts, and recovery actions affecting the desert tortoise in California.

Objectives:

Improve system models to evaluate the direct and indirect effects of solar energy development projects on the Mojave desert tortoise

2. Better assess the relative value of recovery actions for mitigation

Provide scientifically-robust results with appropriate measures of uncertainty to help inform decision-making both at the project and landscape scale

4. Develop tools to support efficient evaluation of proposed projects and recovery action portfolios

Benefits:

The improvements to the software tool will enable the Energy Commission, other agencies, and stakeholders to more rapidly and efficiently obtain estimates of potential impacts of proposed renewable energy projects to the desert tortoise and evaluate alternative mitigation scenarios. This is intended to facilitate the environmental review process by making the development of appropriate mitigation packages and robust impact analyses more efficient.

Title:	Carbon Dioxide Capture and Conversion to Chemical Products				
Agreement Number:	PIR-11-019	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$474,843	Match Funding:	$176,996	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	11/30/2014	Technology Topic:	GHG Sequestration
Award Recipient:	Oakbio, Inc.			End-Market:	Ratepayers

Description:

This project is evaluating the technical and economic feasibility of a novel microbe-based process for the capture and conversion of flue gas CO_2 to bioplastics. It aims to reduce the cost of CO_2 compliance by generating revenues from CO_2 capture and converting CO_2 into a valuable commodity.

Objectives:

Determine the technical and economic feasibility of a novel microbe-based process for the capture and conversion of flue gas CO_2 to bioplastics using a test system at a cement plant

2. Explore potential for scale-up of process at natural gas and coal-fired power plants

Benefits:

Commercial success would lead to environmentally beneficial conversion of flue gas CO_2 to plastic products, thereby sequestering CO_2 in manufactured products and decreasing use of petroleum products in production of plastics.

Title:	Test of Avian Collision Risk of a Closed Bladed Wind Turbine				
Agreement Number:	PIR-11-022	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$716,596	Match Funding:	$174,498	Natural Gas Funding:	$0
Start Date:	6/25/2012	End Date:	3/31/2015	Technology Topic:	Avian Impacts
Award Recipient:	Shawn Smallwood, sole proprietor			End-Market:	Energy Suppliers, Policymakers/Regul

Description:

This agreement studies a shrouded, mixer-ejector wind turbine, testing its safety for avian impacts and comparing how birds react to it versus to open-bladed wind turbines. The purpose of the agreement is to provide field-tested behavior survey methods and data that inform avoidance rates in collision risk models to guide wind turbine siting.

Objectives:

Compare avian interactions with wind turbines between mixer-ejector wind turbines and conventional turbines at known high-fatality sites during the day, night, and various wind and terrain conditions using a short search interval and a before-after, control-impact experimental design.
2. Explain variation in fatality rates by turbine design, flight patterns, and avian interactions with wind turbines (i.e. avoidance behaviors) and provide field-tested behavior survey methods and data that inform avoidance rates in collision risk models and map-based collision hazard models to guide wind turbine siting.

Benefits:

By facilitating identification of the avian migration corridors, this project will increase the production of wind power in California while mitigating the impacts of turbines on avian species.

Title:	CO_2 to Oil Production Using Kiverdi's Novel Microbial System				
Agreement Number:	PIR-11-025	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$747,126	Match Funding:	$587,027	Natural Gas Funding:	$0
Start Date:	6/20/2012	End Date:	3/31/2015	Technology Topic:	GHG Sequestration
Award Recipient:	Kiverdi, Inc.			End-Market:	Ratepayers

Description:

This project will use a newly developed chemoautotrophic technology that uses microbes to convert CO_2 from flue gas sources to produce high-value oils and palm oil-equivalents.

Objectives:

1. Optimize current lab-scale production of palm oil-equivalent using CO_2 and hydrogen (H2
2. Develop a pilot-scale reactor for the microbes, based on lab-scale reactors
3. Create technology to use flue gas feedstock to produce a palm oil-equivalent, and determine the safety profile for the product
4. Determine and achieve a conversion efficiency for CO_2 to palm oil

Benefits:

By developing a new method for capturing carbon from flue gases, this project will help California meet its greenhouse gas emission reduction goals. Additionally, the creation of a revenue source by converting CO_2 to valuable products will reduce overall costs of compliance with the Global Warming Solutions Act of 2006 (AB 32) and Executive Order S-3-05.

Title:	Novel Controls for Time-Dependent Economic Dispatch of Combined Cooling, Heating, and Power in Light Industrial, Commercial, and Institutional Markets with High Temperature Fuel Cells and Gas Turbines				
Agreement Number:	500-10-010	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$300,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	8/30/2010	End Date:	4/30/2015	Technology Topic:	Modeling
Award Recipient:	UC Irvine			End-Market:	Ratepayers

Description:

The goal of this project was to develop physics-based models supporting development of novel controls for combined cooling, heating and power systems. The models were built in the MATLAB- Simulink® framework using a methodology developed by the University of California Irvine. Additionally, the project team developed economic and environmental analysis strategies for these models. The following models were developed and verified by this project: Photovoltaic Model, Lead-acid Battery Model, Lithium-ion Battery Model, Ultra-capacitor Model, Heat Recovery Steam Generator Model, and the Steam Turbine Model. The novel control algorithms and architectures developed were implemented in the combined heat and power facilities of the university's Engineering Laboratory and Central Plant to demonstrate controlled dispatch capability.

Objectives:

Develop first principles dynamic physical models of emerging CCHP technologies
Support installation of equipment to measure dynamic building loads and the dynamic performance characteristics of emerging CCHP technologies
3. Support field installation and performance verification of the novel controls in a CCHP system
4. Support extension of the control strategies to emerging CCHP systems technology

Benefits:

The novel controls developed through this project represent a step forward to helping CHP/CCHP systems become more capable of meeting demands for a larger cross-section of the potential market and will accelerate market adoption of CHP/CCHP technology. Increasing the market potential and market adoption of CHP/CCHP technology will provide California ratepayers with the following benefits:
-lower energy use (improved fuel use efficiency)
-reduced criteria pollutants that can lead to improved air quality
-reduced greenhouse gas emissions, which contributes to meeting state goals for GHG reduction and lessens impacts on the global climate
-lower ultimate cost of electricity and heat.

Title:	Development and Demonstration of a Novel High-Temperature Fuel Cell Absorption Chiller CCHP System				
Agreement Number:	PIR-09-018	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$1,480,000	Match Funding:	$2,140,000	Natural Gas Funding:	$0
Start Date:	10/25/2010	End Date:	3/31/2015	Technology Topic:	Hybrid Plants
Award Recipient:	National Fuel Cell Research Center - UC Irvine			End-Market:	Ratepayers

Description:

The overall intent of this project is to proactively accelerate the deployment of high temperature fuel cell-chiller technology into the California market by developing and demonstrating a high-temperature fuel cell integrated with an absorption chiller combined cooling, heating and power (CCHP) system at a building facility in the UC Irvine campus. To achieve this goal, the project has developed an optimized integrated high-temperature/absorption chiller system design. Such optimized design is being installed at a building on campus which will later on be demonstrated and evaluated for performance and market value in California.

Objectives:

1. Optimize Design
2. Establish Power Purchase Agreement (PPA) and Complete Engineering Drawings
3. Manufacture, Install, and Commission the System
4. Evaluate System Performance
5. Evaluate System Economics and Market Competitiveness
6. Transfer Technology and Advance Market Engagement
7. Evaluate System Economics and Market Competitiveness
8. Transfer Technology and Advance Market Engagement

Benefits:

This project will help develop and bring to market advanced electricity generation technologies that exceed applicable standards to reduce greenhouse gas emissions from electricity generation, and that benefit electric utility customers by developing, demonstrating, and commercializing an optimized integrated high-temperature/absorption chiller system design. If successful, this project will help displace electricity required today for chillers, reduce emissions of criteria pollutants and greenhouse gases (GHGs), increase reliability for the customer, and reduce demand for additional transmission and distribution circuits.

Title:	Arc Fault Circuit Interrupter Development for Residential DC Electricity				
Agreement Number:	500-01-043	Project Number:	16	Research Stage:	Applied Research
Electricity Funding:	$149,808	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	10/1/2013	End Date:	3/30/2015	Technology Topic:	ZNE
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Ratepayers

Description:

This research will develop an Arc Fault Circuit Interrupter (AFCI) for a DC-powered house. This project will focus on increasing California's electric power supply efficiency with safety as the primary objective. Arcing events in which there is an electrical breakdown in the circuits are a significant fire risk, and AFCIs can significantly reduce this risk. AFCIs are currently in development for 80V or higher photovoltaic circuits, but this research will develop a prototype AFCI for DC household plug circuits operating at 24-48V and integrate this technology into a Smart DC Wall Plug.

The AFCIs required in residential AC wiring cannot detect arcing downstream of any AC-DC converters. The project will develop a system which is able to detect arcing downstream of a DC-DC converter to provided added safety over what is currently required by most electrical codes in the U.S.

Objectives:

1. Expand on existing literature search, to ensure we have all available information on the topic
2. Design and build experimental set-up to simulate series, parallel, and ground arcs
3. Characterize spectral response of arcing behavior in current from DC power supply
4. Design, simulate and test arc detector to identify series, parallel, and ground arcs on both sides of the Smart DC Wall Plug
5. Consult with industry collaborators on design and practical considerations to ensure adoptability of the AFCI
6. Design and incorporate interrupter with arc detector to appropriately respond to arcing conditions
7. Write Interim Report on (1) to (6) and conduct Critical Project Review meeting

Test AFCI design to ensure it works under a wide-range of voltages, currents, load-types, and various conditions. Iterate on AFCI design based on prior testing

Benefits:

This grant will Improve the reliability/quality of California's electricity by reducing service interruptions through expanded service options and new system-wide capabilities while also improving the energy cost/value of California's electricity by providing real-time information and a means to automatically respond to supply-side problems. This grant also maximizes market connection by reducing the installed cost of energy-related information, communication, and control technologies.

Title:	Repetitive And Adaptive Control of Distributed Generation for Seamless Transition Between Grid-tied And Off-grid Modes				
Agreement Number:	500-01-043	Project Number:	17	Research Stage:	Applied Research
Electricity Funding:	$150,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	10/1/2013	End Date:	9/30/2014	Technology Topic:	Microgrid
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Ratepayers

Description:

This research will focus on developing the control system for microgrids to safely and efficiently operate in all operation modes. The proposed control system objectives are to provide seamless transition between grid-tied and off-grid modes and guarantee superior power quality in all operation modes. The proposed control system will be able to improve the voltage control at the distribution level and also mitigate the variable distributed energy resource impacts. The proposed control approach has the potential to improve the transient performance, efficiency, and power quality compared to the current methods and practice. Hardware-in-the-loop simulations to compare the proposed control methodology with benchmark performance will be performed.

Objectives:

Develop a microgrid real-time simulation system including four different type of DERs: battery, photovoltaic, wind turbine, and gas turbine. Each of these DERs has different response time, power capacity, and variability
2. Develop embedded control hardware for the microgrid system developed in (1)
3. Integrate output of (1) and (2) as a real-time hardware in the loop (HIL) simulation
4. Create a benchmark performance using industrial standard control methods
5. Write Interim Report on (1) to (4) and conduct Critical Project Review meeting
6. Develop the Adaptive Model Predictive Control for the HIL system
7. Develop the Repetitive Control for the HIL system
8. Integrate the two control methods and compare the test results with benchmark performance developed in (4)

Benefits:

This grant will Improve the reliability/quality of California's electricity by reducing service interruptions through expanded service options and new system-wide capabilities while also improving the energy cost/value of California's electricity by providing real-time information and a means to automatically respond to supply-side problems. This grant also maximizes market connection by reducing the installed cost of energy-related information, communication, and control technologies.

Title:	Porous Silicon-based Lithium Ion Anodes for Secondary Batteries				
Agreement Number:	500-01-043	Project Number:	18	Research Stage:	Applied Research
Electricity Funding:	$150,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	10/1/2013	End Date:	3/30/2015	Technology Topic:	Battery
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Ratepayers

Description:

The research objectives are to optimize the silicon etching process for lithium ion battery anodes, connections through which electric current flows in or out of a rechargeable battery, to increase the battery cycle life and capacity. The research team aims to tailor the porous silicon etch process to enable the structure to withstand the repeated volume changes and stresses associated with charging and discharging the battery. The research team also aims to develop a new method to chemically tailor a carbon-based coating on the porous silicon anode for optimal electrical conductivity and enhanced structural stability. The team will then construct and test the performance of the anode materials and evaluate their behavior.

Objectives:

Optimize silicon etching conditions to optimize pore size (~40nm) and thickness (~10nm) of silicon pore walls (4 months), by etching single-crystal silicon wafers using electrochemical anodization in ethanolic hydrofluoric acid (HF) solutions

Develop new chemistry to tailor the carbon coating on porous silicon for optimal electrical conductivity and enhanced structural stability

3. Construct and test electrochemical properties of the anode materials in standard lithium ion half-cells

Analytical Transmission Electron Microscopy will be used to study the electrode materials in order to fully characterize the surfaces and interfaces of the porous Si material in both powder and thin film forms

5. Test the performance of the anode materials in standard lithium ion halfcells using Electrochemical Impedance Spectroscopy

6. Evaluate behavior of anode materials in standard lithium ion half-cells in solid and polymer electrolyte junctions

Benefits:

This grant will Improve the reliability/quality of California's electricity by reducing service interruptions through expanded service options and new system-wide capabilities while also improving the energy cost/value of California's electricity by providing real-time information and a means to automatically respond to supply-side problems. This grant also maximizes market connection by reducing the installed cost of energy-related information, communication, and control technologies.

Title:	Smart Power for the Smart House: Inverter Connections, Power Factor Corrections, and Peak Reductions				
Agreement Number:	500-01-043	Project Number:	19	Research Stage:	Applied Research
Electricity Funding:	$397,288	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	3/3/2014	End Date:	3/30/2015	Technology Topic:	Controllable/ regulating Inverter
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Ratepayers

Description:

This proposed research will develop an Active Power Factor Correction (APFC) Inverter to control the power factor in real time to reduce residential peak load, improving power factors, and advancing load monitoring technology in zero net energy (ZNE) homes. The APFC will then be tested along with wireless load monitoring hardware in a smart ZNE home in Davis, California. The compiled and analyzed smart home data will be used to create a ZNE home baseline model for input into a feeder-level electrical grid model to simulate peak load reduction.

Objectives:

Develop & Bench Test Active Power Factor Correction (APFC) Inverter
2. Field Evaluation of APFC Inverter and Load Monitoring Tool in ZNE Residence
3. Load Signature Analysis for Wireless Monitoring and Control
Parametric Assessment of the Grid Benefits of APFC in Combination With Integrated Mechanical Design and Control for Peak Shifting
5. Prepare Final Report

Benefits:

This grant will Improve the reliability/quality of California's electricity by reducing service interruptions through expanded service options and new system-wide capabilities while also improving the energy cost/value of California's electricity by providing real-time information and a means to automatically respond to supply-side problems. This grant also maximizes market connection by reducing the installed cost of energy-related information, communication, and control technologies.

Title:	Control of Networked Electric Vehicles to Enable a Smart Grid with Renewable Resources				
Agreement Number:	500-01-043	Project Number:	20	Research Stage:	Applied Research
Electricity Funding:	$400,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	3/3/2014	End Date:	3/30/2015	Technology Topic:	Distribution Management
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Ratepayers

Description:

This proposed research will develop control technologies to leverage the aggregated energy storage capabilities of electric vehicles that are networked together to improve renewable generation reliability, to support distributed system operation, and to supply peak load demand and ancillary support to the grid. These objectives will be achieved by using communication, computing, and control technologies for renewable resources, energy storage units, and networked electric vehicles (NEVs) management to enable a smart grid with renewable resources. NEVs are electric vehicles aggregated on a distribution grid to provide coordinated peak power support to increase power quality, greater grid stability, and reliability.

Objectives:

Develop a vehicle-to-grid system using CHAdeMO protocol. (UCLA)
2. Create a DER object to represent NEV within ISO/IEC 15118 and IEC 61850 protocols (with IEEE 1547 compliance). (UCLA)
Develop a charge and discharge device based on the existing WINSmartEVTM charging system - this device will be called the ÒGrid and User Friendly NEV ControllerÓ or simply the NEV controller. (UCLA)
Install a test PV solar unit and establish communication and control with the new DER object module and integrate it with the NEV controller. (UCLA)
5. Design a scalable open-architecture mesh network of NEVs based on WINSmartGridTM. (UCLA)
6. Design smart algorithms for charging and discharging of NEVs for peak shaving. (UCLA and UCSD)
7. Develop optimal power flow (OPF) algorithms for VAr control. (UCSD)
8. Develop distributed control based on OPF NEVs in distribution system. (UCSD)

Benefits:

This grant will improve the reliability/quality of California's electricity by reducing service interruptions through expanded service options and new system-wide capabilities while also improving the energy cost/value of California's electricity by providing real-time information and a means to automatically respond to supply-side problems. This grant also maximizes market connection by reducing the installed cost of energy-related information, communication, and control technologies.

Title:	Enabling Real-Time Residential Pricing with Closed Loop Customer Feedback				
Agreement Number:	500-01-043	Project Number:	21	Research Stage:	Applied Research
Electricity Funding:	$199,932	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	3/3/2014	End Date:	3/30/2015	Technology Topic:	Market (Rates)
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Ratepayers

Description:

The proposed research will develop a closed-looped customer feedback and cloud-based price control method to allow utilities to more accurately forecast future energy demands to better regulate customer pricing. This control method will be automatic and provide real-time balancing of energy demand and generation. This objective will be achieved by reconciling forecasted data with real power consumption and send real-time pricing information to the customer through mobile messaging (smartphone application). This solution will be deployed with energy management and dynamic pricing solutions in cooperation with San Diego Gas & Electric.

Objectives:

Expand on existing literature search, to ensure we have all available information on the topic.
2. Identify Test Sites and recruit consumers to take part in the research
3. Development of in home display and energy management application
Develop Cloud to Mobile Messaging application. Develop the cloud application for real time price computations based on demand elasticity
5. Integrate smart meter data into cloud application to close the loop in behavior monitoring and real time pricing. Deploy Application at selected consumer premises
6. Write Interim Report on Tasks 1 to 5 and conduct Critical Project Review meeting
Analyze Historical Power consumption data provided by SDG&E California Green Button Data, this data is available with permission of the consumer in hourly intervals
8. Test closed loop real time pricing application at consumer premises in cooperation with SDG&E
9. Integrate Real Time Pricing Application with the home energy master controller
10. Write Final Report

Benefits:

This grant will Improve the reliability/quality of California's electricity by reducing service interruptions through expanded service options and new system-wide capabilities while also improving the energy cost/value of California's electricity by providing real-time information and a means to automatically respond to supply-side problems. This grant also maximizes market connection by reducing the installed cost of energy-related information, communication, and control technologies.

Title:	Pacific Gas & Electric Energy Storage Demonstration				
Agreement Number:	500-09-027	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$3,300,000	Match Funding:	$8,000,000	Natural Gas Funding:	$0
Start Date:	6/15/2010	End Date:	6/30/2014	Technology Topic:	Battery
Award Recipient:	Pacific Gas and Electric Company			End-Market:	Ratepayers

Description:

PG&E is demonstrating two sodium-sulfur battery energy storage systems: a two megawatt system at PG&E's Vaca-Dixon Substation and a four megawatt system at Hitachi Global Storage Technologies in San Jose. Both systems have more than six hours of energy storage capacity. The battery system in San Jose is currently the largest grid-connected battery in California and will help reduce the number of outages for the Hitachi facility. The battery system at the Vaca-Dixon substation will help smooth out the variability of the power generated by the nearby Vaca-Dixon solar plant, which produces up to two megawatts.

Objectives:

Install and monitor two large-scale, sodium-sulfur battery energy storage systems and document the experience, costs, schedule, performance, and lessons learned

Demonstrate the use of the storage systems to enhance service reliability and power quality on the PG&E transmission and distribution system

Demonstrate the use of the storage systems to enhance the value of wind and/or solar generation on the PG&E transmission and distribution system

4. Compare the Vaca-Dixon and Hitachi storage systems to other sodium-sulfur battery energy storage system projects

5. Transfer results and lessons learned via a workshop to California utilities to enable energy storage deployments in California

Benefits:

Helped mitigate the variability of a large PV system on a distribution circuit and improved the electric service to a large industrial customer at the end of a long distribution circuit. Provided more real-world information about the performance of a large-scale, sodium-sulfur battery energy storage system at both a distribution substation and an industrial customer's facility.

Title:	Customer Premise Network design, Cyber Security issue identification and Simulations of DG impacts on the Distribution System for the benefit of California Investor Owned Utility Ratepayers.				
Agreement Number:	500-09-039	Project Number:	1	Research Stage:	Technology Development
Electricity Funding:	$3,400,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/1/2010	End Date:	3/31/2015	Technology Topic:	Monitoring and
Award Recipient:	University Enterprises, Inc. (Auxiliary Organization to California State University, Sacramento)			End-Market:	Ratepayers

Description:

This project involves coordinating and performing research to enable a smart grid for statewide reliability and efficiency improvements through the following activities:

1) Develop and establish mitigation algorithms to prevent significant events in the power grid and increase power flows.
2) Develop and demonstrate smart grid technologies to increase communication and control in the power grid.
3) Implement cyber security enhancements into smart grid equipment.
4) Develop methods, standards and demonstrations to increase interoperability of smart grid technologies.

Objectives:

1. Create the California Smart Grid Center and identify the applied RD&D needs to solve practical and technical issues
2. Engage in applied research, testing, demonstrations, and technology transfer of Smart Grid component technologies
3. Facilitate practical solution development for the integration of smart grid infrastructure
4. Conduct outreach efforts for a wide range of California stakeholders
5. Provide, evaluate, quantify, and document the tangible benefits of Smart Grid Center activities to California ratepayers

Benefits:

Key benefits of this research to California citizens include providing more choices for utility customers to reduce electricity costs and effective use of localized generation to reduce power outages.

Title:	WESTCARB PHASE III - BKI				
Agreement Number:	500-09-045	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$3,941,354	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/30/2010	End Date:	3/30/2014	Technology Topic:	GHG Sequestration
Award Recipient:	Bevilacqua-Knight, Inc.			End-Market:	Energy Suppliers

Description:

This agreement provides research to define least-cost GHG mitigation strategies appropriate for California, including assessing the potential for carbon sequestration. This phase of WESTCARB involves updates of the large industrial point source CO_2 emissions data in its geographic information system (GIS) database to meet the needs of users, including U.S. DOE, which publishes an atlas on a biennial basis. Similarly, this phase provides updates to its CCS economic analyses. These studies are key to refining data on which to base CCS policies and public-private technology investment decisions.n U.S. DOE's award to the Energy Commission for the third phase of WESTCARB presumed that the technical assessment, management, and public outreach team, and the working relationships established during Phases I and II, would carry forward to ensure continuity (a portion of Phases II and III are being conducted concurrently), reduce project risk, and maximize the value and benefits of prior experience and lessons learned.

Objectives:

1. Further characterize regional data on large industrial sources of CO_2
2. Update and expand CCS economic evaluations to better understand opportunities for future CCS projects in CA
3. Provide technical assistance in the evaluation of CCS application for natural gas combined cycle power plants
4. Develop and disseminate WESTCARB outreach materials

Benefits:

The technical and economic information on industrial CO_2 capture and storage (CCS) provided by the WESTCARB project will allow state policymakers and the public to better assess the role that CCS could play in achieving the greenhouse gas emission reductions set forth in AB 32 as well as the long-term goal established by Executive Order S-3-05 (80% below 1990 emission levels by 2050).

Title:	Renewable Resource Management at UCSD				
Agreement Number:	500-10-043	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$2,994,298	Match Funding:	$1,964,644	Natural Gas Funding:	$0
Start Date:	6/20/2011	End Date:	3/31/2015	Technology Topic:	Forecasting
Award Recipient:	The Regents of the University of California, San Diego			End-Market:	Ratepayers

Description:

This project involves four separate research areas in solar forecasting, distributed energy storage, the observability of the microgrid by the California Independent System Operator (CAISO), and using renewable energy for charging of electric vehicles. The forecasting research project will develop a better intra-hour forecast for solar photovoltaics. This will be accomplished through 'Skytracker' devices that monitor cloud movement near large PV installations. The distributed energy storage systems project will demonstrate an integrated solution that combines PV and electric energy storage to mitigate the intermittency of renewable generation. The microgrid observability project will provide the CAISO with monitoring capability for microgrids such as UCSD's. A communication link will be installed and established between the CAISO and UCSD to provide full observability of the operation of the microgrid. The renewable charging of electric vehicle project demonstrates a Direct Current linked chargeport to maximize the use of renewable energy resources and reduce inverter losses.

Objectives:

Document that electric vehicle (EV) emission levels below 130 g CO_2e/mi can be achieved with renewable distributed energy resources as the charging source

2. Demonstrate that a direct current linked chargeport for charging of EVs can mitigate variable renewable generation
3. Demonstrate that bi-directional, vehicle-to-grid operability provides ancillary grid services, storage, and/or generating assets
4. Document that renewable resources provide EV charging at a delivered cost comparable to the Experimental Tariff Rates approved by the CPUC for SDG&E
5. Demonstrate that a direct current linked chargeport is more efficient than an AC linked chargeport

Benefits:

Benefits to ratepayers include greater reliability of solar renewable energy through improved solar forecasting as well as electric energy storage systems combined with solar PV technology; improved renewable energy integration into the electrical energy grid; and using renewable energy resources for charging electric vehicles.

Title:	Using High Speed Computing to Estimate the Amount of Energy Storage and Automated Demand Response Needed to Support California's RPS.				
Agreement Number:	500-10-051	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,750,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/30/2011	End Date:	6/30/2014	Technology Topic:	Planning
Award Recipient:	Lawrence Livermore National Laboratory			End-Market:	Ratepayers

Description:

This study assesses the ability of demand response and energy storage to provide regulation, load following, and other ancillary services to the California power grid. The report describes models and data sets for renewable generation, including the inherent uncertainty and variability. The report also describes probability based (or, stochastic) production simulation models and statistical analyses to evaluate how automated demand response and energy storage are utilized in concert with other resources in the system. The value of energy storage and demand response is estimated by identifying the avoided costs of the conventional hydro and fossil resources that they displace for providing regulation, load following, and energy arbitrage functions.

Objectives:

1. Develop scenarios that probabilistically characterize requirements for control with high renewable penetration
2. Develop simulation test bed that includes forecasting, unit commitment, and economic dispatch using scenarios
3. Characterize performance of a range of candidate demand response, energy storage, and generation technologies

Benefits:

This study will benefit California ratepayers by informing policy makers of cost impacts associated with renewable generation, energy storage, demand response, and other goals for development and operation of the State power grid. Goals could be set to achieve environmental and other benefits without imposing an undue burden on California ratepayers. Given the billions of dollars in capital investments and operating costs associated with the power grid, a small improvement in decision making could provide substantial savings.

Title:	Determining Best Location for Energy Storage to Maximize Effectiveness with Residential Renewable Generator Clusters				
Agreement Number:	500-11-006	Project Number:	1	Research Stage:	Technology Development
Electricity Funding:	$539,350	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	11/7/2011	End Date:	5/7/2014	Technology Topic:	Battery
Award Recipient:	San Diego Gas & Electric Company			End-Market:	Energy Suppliers

Description:

This project aims to address operating challenges with renewable generation by appropriately dispatching distributed energy storage systems to offset load or generation changes. Customer-owned solar PV systems present challenges because their generation is variable and intermittent, and these systems are appearing on utility grids in increasing numbers. This project installed three controllable energy storage systems to explore strategies to improve distribution grid operations.

Objectives:

1. Develop criteria for the installation of distributed energy storage devices
2. Install the energy storage devices on a distribution feeder
3. Develop techniques for managing and dispatching the energy storage devices
4. Test the effectiveness of the storage in mitigating renewable generation intermittency
5. Quantify additional benefits of the storage systems (e.g. peak shaving, reactive power support)

Benefits:

Due to siting challenges, the three energy storage devices were not installed on a single distribution feeder as originally planned; they were procured and are installed at a residential location, at a commercial location, and at SDG&E's test center. Once reliable remote operation of the devices had been achieved, they were successful at mitigating intermittent generation in numerous operational modes. The final results and quantification of the benefits is expected in late 2014.

Title:	Electric Vehicle Charging Simulator for Distribution Grid Feeder Modeling				
Agreement Number:	500-11-007	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$680,000	Match Funding:	$592,000	Natural Gas Funding:	$0
Start Date:	11/7/2011	End Date:	5/16/2014	Technology Topic:	Loading Monitor
Award Recipient:	San Diego Gas & Electric Company			End-Market:	Ratepayers

Description:

The goal of this project is to simulate the load and power quality effects of multiple electric vehicles charging on a distribution circuit. This will help determine electric vehicles' impact on grid performance and operation. The project is also demonstrating an integrated approach to electric vehicle charging that incorporates renewable generation, battery energy storage and controllable charging.

Objectives:

Design a plug-in electric vehicle (PEV) charging simulator to be used for testing of distribution grid arrangements

2. Build a model of a typical electrical circuit with high PEV penetration

Integrate the PEV simulator with the circuit model and conduct a series of tests to evaluate the impact of PEVs on a distribution circuit

Demonstrate the integration of PEVs with energy storage and renewable generation to evaluate the ability to offset charging load through optimized control

Benefits:

This project consists of two main activities: 1) the design and assembly of a state-of-the-art PEV charging simulator to model in detail the impacts of electric vehicle charging on SDG&E's distribution grid, and 2) a small real-world demonstration site that includes PEV charging, stationary battery energy storage, and solar PV generation integrated with optimization controls. The demonstration site has provided valuable data to be presented and contextualized in the final report. The PEV charging simulator is not only producing valuable PEV impact data; due to its use of state-of-the-art transformerless inverters, the simulator may additionally be used for modeling smart inverter impacts on the distribution grid, exceeding expectations.

Title:	Wind Ramp - Short Term Event Prediction Tool - Development and Implementation of an Analytical Wind Ramp Prediction Tool for the CAISO				
Agreement Number:	500-11-009	Project Number:	1	Research Stage:	Technology Development
Electricity Funding:	$398,662	Match Funding:	$109,364	Natural Gas Funding:	$0
Start Date:	12/15/2011	End Date:	12/15/2014	Technology Topic:	Wind
Award Recipient:	The Regents of the University of California, Davis			End-Market:	Energy Suppliers

Description:

The goal of this project is to better predict short-term wind events, known as wind ramps, and to provide more accurate information to grid operators regarding these events.

A wind ramp event forecast tool will be developed for the California Independent System Operator renewable desk operators. This forecast will give the operators notice of a sudden change of power with some level of confidence that the event will occur. For instance, the tool will indicate there is an 80 percent chance that a front with winds gusting to 50 mph will pass through the Solano Wind Resource Area within the next 45 minutes. This tool will enhance the operators' decision-making process for procurement of ancillary services, unit commitment, and dispatch.

Objectives:

1. Determine what defines a wind ramp event
2. Determine what atmospheric conditions will most likely cause a ramp event
3. Determine when ramp events are most likely to affect the grid
4. Determine what is the best way to measure ramp forecast accuracy
5. Determine what situational display tools are best to present upcoming ramp events
6. Determine how far in the future can a ramp event be predicted

Benefits:

This project will lead to the creation of a wind ramp event forecast tool for the California Independent System Operator renewable desk operators. This forecast tool will give operators notice that a sudden change of power will occur with some level of confidence that the event will occur. It will enhance the operators' decision-making process for procurement of ancillary services, unit commitment, and dispatch. This will lead to more effective use of wind generation resources with concurrent reduction of polluting greenhouse gas emissions, and will increase the reliability of California's electric grid.

Title:	WindSENSE-Determining the Most Effective Equipment for the CAISO to Gather Wind Data for Forecasting				
Agreement Number:	500-11-010	Project Number:	1	Research Stage:	Technology Development
Electricity Funding:	$646,661	Match Funding:	$76,986	Natural Gas Funding:	$0
Start Date:	2/1/2012	End Date:	3/31/2015	Technology Topic:	Wind
Award Recipient:	The Regents of the University of California, Davis			End-Market:	Energy Suppliers

Description:

The goal of this project is to deploy atmospheric remote sensing systems at locations that will achieve the largest possible reduction in short-term forecast error for the California Independent System Operator at selected wind farm sites in the Tehachapi Wind Resource Area in California. Deploying this remote sensing equipment will help mitigate the problems and reduce the costs of integrating large amounts of wind-based electric power into the grid.

Objectives:

Determine whether Light Detection and Ranging (LiDAR) and radiometer units a cost-effective way to gather data to improve short-term power prediction

Determine the relative impact of the LiDAR, radiometer and the combined dataset on wind power forecast performance (i.e., is most of the value in one sensor or the other or is there substantially more value in operating both units?)

3. Measure the improvement in forecast performance can be achieved by the use of data from these sensors

4. Determine what types of forecasts achieve the most and least impact from the LiDAR and radiometer dataset

Determine whether the results (i.e., the identified best locations) of the LLNL-sponsored observation targeting study provide effective guidance for the optimal deployment of sensors

6. Identify the physical processes that cause wind ramp events in Tehachapi Pass

Provide a foundation for the planning and implementation of a larger multi-sensor field campaign in the Tehachapi Wind Resource Area to take place in the near future

Benefits: This project benefits California by addressing the California Independent System Operator's (CAISO) need for an effective way to collect data to create short-term wind forecasts. Creating accurate short-term wind forecasts will help mitigate the problems and reduce the costs of integrating large amounts of wind-based electric power into the grid. Benefits include reduced dependency on fossil fuel imports, reduced greenhouse gas emissions, making the grid more reliable and stable, and increasing sources of renewable energy to help meet California's Renewable Portfolio Standard, which requires renewable energy resources to be 33% of total procurement by 2020.

Title:	Recovery Act - California Smart Grid Workforce Development Network				
Agreement Number:	500-11-011	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$83,355	Match Funding:	$749,992	Natural Gas Funding:	$0
Start Date:	3/26/2012	End Date:	5/26/2014	Technology Topic:	Other
Award Recipient:	University Enterprises, Inc. (Auxiliary Organization to			End-Market:	Energy Suppliers

Description:

University Enterprises Inc. was awarded $749,992 under the United States Department of Energy's ARRA of 2009 Grant FOA, DE-FOA-0000152 - Workforce Training for the Electric Power Sector for the California Smart Grid Workforce Development Network project. This project will support the development of California's Smart Grid workforce, engaging electric utilities, California State University campuses, California Community Colleges, labor unions, and Smart Grid manufacturers. PIER matching funds were crucial in bringing in the ARRA grant funding to support California Utilities' needs in workforce related to Smart Grid technologies. University Enterprises Inc. submitted an application to PIER for cost share funding in the amount of $83,355.

Objectives:

1. Establish the California Smart Grid Workforce Development Network
2. Create positive impacts on Statewide Smart Grid workforce development
3. Create a model for Smart Grid workforce development

Benefits:

The Network offers many benefits to its utilities and education stakeholders. Through this Network, the California Smart Grid Center has a powerful platform for creating linkages between technology advances by private industry, smart grid deployment by the utilities, and a workforce whose ongoing development is synchronized with the evolution of the grid.

Title:	Implementation of Demand Response in a University Campus				
Agreement Number:	500-11-013	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$499,999	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	4/2/2012	End Date:	3/31/2015	Technology Topic:	Whole Building
Award Recipient:	The Regents of the University of California on behalf of the			End-Market:	Ratepayers

Description:

This project will perform research on a new architecture design for AutoDR by interfacing UCLA's WINSmartGrid communications platform with OpenADR, creating a new AutoDR model based on this architecture, performing simulations on the AutoDR model, and conduct a field test in a UCLA residential campus dwelling.

Objectives:

Investigating, demonstrating, and quantifying the potential for peak load reduction via an AutoDR research demonstration project in UCLA

2. Researching, creating, and demonstrating AutoDR within the UCLA campus residential dwelling load

Researching, testing, and evaluating the information and network interface between OpenADR platform from Lawrence Berkeley National Laboratory and WINSmartGrid platform from UCLA for demonstrating AutoDR

Researching and testing the ability of the campus residential infrastructure using WINSmartGrid to support and carry AutoDR signals generated using OpenADR and the ability and effectiveness of these signals to reach the target loads and provide the desired peak load reduction via AutoDR

Investigating and researching scale-up of the campus demonstration DR architecture into that of the local utility (Los Angeles Department of Water and Power) infrastructure model

6. Researching and evaluating customer response and behavior to AutoDR programs

7. Implementing the Technology Transfer Plan

Proposing hypotheses for the success of AutoDR in campus residential dwelling loads and prove, disprove, or partially prove these hypotheses

Benefits:

DR benefits include better grid balance, reduction in lost energy, and increase in grid efficiency. During peak demand on a hot summer's afternoon, a demand response signal is used to reduce the energy demand for short time periods so that the grid operator does not need to obtain electricity from economically and environmentally inefficient peaker plants. Offering DR capability to residential customers could result in substantial benefits to the grid operator, the consumer, society, and the environment.

Title:	Advanced Control Technologies for Distribution Grid Voltage and Stability with Electric Vehicles and Distributed Renewable Generation				
Agreement Number:	500-11-018	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,535,725	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/30/2012	End Date:	3/30/2015	Technology Topic:	Smart Grid
Award Recipient:	Pacific Gas and Electric Company			End-Market:	Ratepayers

Description:

(No more than three complete sentences)

Objectives:

1. Investigate system voltage and end-of-line issues and determine if they can be managed through centralized control distribution line equipment
2. Identify significant issues directly related to high penetration levels of electric vehicles, PV, or DG
3. Identify intermittency and variability and issues with EV, PV, and other DG
4. Identify high/low voltage effects on utility customers caused by EV and DG at higher penetration levels
5. Identify mitigation measures that may be necessary to ensure that utility systems will operate safely and reliably

Benefits:

Improve future distribution planning and operations. Research results include open source models that will be made available to the public.
Better understanding of how solar PV impacts voltage levels on the distribution system.
Development of techniques for analyzing the time-variant nature of solar PV and its interaction with system loads.
Preliminary development of mitigation strategies for addressing potential voltage issues caused by solar PV.

Title:	Distribution System Field Study with California Utilities to Assess Capacity for Renewables and Electric Vehicles				
Agreement Number:	500-11-019	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,167,380	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/30/2012	End Date:	3/31/2015	Technology Topic:	Distribution Management
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Ratepayers

Description:

Gather existing distribution monitoring data from the three IOUs and SMUD, and use this information to develop accurate models and simulate increasing penetrations of distributed, renewable generation and electric vehicles on those circuits. This project will help the four utilities plan for strategic upgrades to their distribution monitoring systems.

Objectives:

Coordinate the collection of empirical data by several California utilities on a representative sample of distribution circuits
Analyze the data for critical information about the performance of different distribution circuits at different penetration levels of distributed generation and electric vehicles
Extract and combine information from prior distribution circuit studies to build on existing knowledge and avoid duplication of effort
Test, validate, and develop models of distribution circuits with high penetrations of distributed resources that capture interactive effects at high resolution
5. Share results and conclusion with California utilities and the CAISO

Benefits:

This project will help the participating California utilities improve their existing distribution monitoring systems so that higher penetrations of distributed resources can be accommodated on the distribution grid.

Title:	Underground Electric Cable Diagnostics: Miniaturize, Field Test, and Commercialize State of the Art Sensors				
Agreement Number:	500-11-021	Project Number:	1	Research Stage:	Technology Development
Electricity Funding:	$1,200,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	3/16/2015	Technology Topic:	Other
Award Recipient:	The Regents of the University of California on behalf of the California Institute for Energy and Environment			End-Market:	Energy Suppliers

Description:

The purpose of this project is to complete and commercialize diagnostic tools to determine the condition of underground electric cables. The length of this agreement is 24 months.

Objectives:

1. Install previously developed sensor prototypes in the field and in the lab
2. Run extended long-term testing for six or more months
3. Collect long-term data from the sensors
4. Develop techniques to assess cable integrity and devise means to improve the reliability of the sensors
5. Research ways to miniaturize diagnostic sensors using micro- and nano-fabrication techniques
6. Develop energy harvesting technologies for the purpose of self-powering the sensors
7. Perform life-cycle analysis of the new sensors with the goal of achieving a 20-year life of the sensors

Fabricate the new sensors in the Contract's state-of-the-art micro-/nano-fabrication facilities. Testing of the sensors will be in both laboratory and field environments

9. Work with stakeholders such as the California IOUs, packaging/MEMS companies, and Agilent Technologies, to foster discussion of commercializing the sensors. Conduct design-for-manufacturing analysis to engineer and harden the sensors for widespread use. Work with the stakeholders to develop a commercialization plan.

Benefits:

The benefits provided by this project are lower instances of underground distribution cable failures. A more reliable electric grid. Improved customer safety. Lower economic impact to business that lose power from cable failures. Reduced operations and maintenance cost to the utilities.

Title:	Vehicle-Grid Integration Roadmap				
Agreement Number:	KEMA-11-006	Project Number:	1	Research Stage:	Road Mapping
Electricity Funding:	$109,965	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	7/1/2013	End Date:	2/3/2014	Technology Topic:	EV Charging Stations
Award Recipient:	KEMA, Inc.			End-Market:	Ratepayers

Description:

This work authorization was to assist the California Independent System Operator in creating the Vehicle-Grid Integration Roadmap. The Roadmap is the first deliverable under Governor Brown's 2013 ZEV Action Plan to be completed, and it outlines the paths and priorities for commercializing the use of electric vehicles to improve power grid reliability.

Objectives:

Assemble stakeholder input from two previous California ISO workshops into sequential drafts of the Vehicle-Grid Integration Roadmap

2. Conduct additional research where gaps exist in the material collected

3. Support the California ISO and the Energy Commission in conducting workshops soliciting stakeholder input

4. Finalize and distribute the Vehicle-Grid Integration Roadmap

Benefits:

Through this work authorization, DNV GL (formerly KEMA) assisted the California Independent System Operator (CAISO) in developing and publishing the Vehicle-Grid Integration Roadmap in consultation with the Energy Commission, the Public Utilities Commission, the Air Resources Board, and stakeholders. DNV GL helped facilitate two workshops at the CAISO and the Energy Commission to collect input from stakeholders, and worked on successive frameworks and drafts of the Roadmap. The Vehicle-Grid Integration Roadmap is the first deliverable under Governor Brown's ZEV Action Plan to be completed, and is a valuable resource for stakeholders to develop methods to integrate electric vehicle charging with the power grid and to accomplish California's clean energy goals.

Title:	Wind Firming EnergyFarm				
Agreement Number:	PIR-10-029	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$1,000,000	Match Funding:	$45,700,000	Natural Gas Funding:	$0
Start Date:	7/1/2011	End Date:	3/31/2015	Technology Topic:	Battery
Award Recipient:	Primus Power Corporation			End-Market:	Energy Suppliers

Description:

Primus Power Power's 25 MW/75 MWh energy storage system will replace a planned 25 MW fossil fuel plant required to compensate for the variable nature of wind energy and to provide load shifting capabilities. The primary application for the EnergyFarm is energy balancing. Secondary applications include targeted renewable firming and strategic local peak shaving, automated load shifting, ancillary services, reactive power compensation, and emissions reduction.

Objectives:

1. Trigger rapid adoption of grid storage systems in the U.S. by demonstrating a low-cost, robust and flexible EnergyFarm™
2. Accelerate adoption of renewable energy and enhance grid stability by firming the output of wind and solar farms
3. Demonstrate improved grid asset utilization by storing energy during off-peak periods for dispatch during local load peaks
4. Establish an advanced battery manufacturing industry in the U.S.
5. Reduce emissions and water usage by utilities

Benefits:

Benefits of the project include the creation of jobs and deployment of new storage technologies which will help customers more efficiently and effectively address renewables integration, transmission congestion, ancillary services, and transmission and distribution capital requirements. Facilitating the integration of intermittent renewable resources in a way that will help improve grid reliability and stability will benefit ratepayers.

Title:	SMUD SCADA Retrofit				
Agreement Number:	PIR-10-034	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$1,000,000	Match Funding:	$307,591,845	Natural Gas Funding:	$0
Start Date:	6/1/2011	End Date:	3/31/2015	Technology Topic:	AMI/Smart Meters
Award Recipient:	Sacramento Municipal Utility District			End-Market:	Energy Suppliers

Description:

This project will deploy a comprehensive regional smart grid solution built upon the installation and operation of an end-to-end smart grid that extends from the transmission system to the smart meters of all 600,000 SMUD customers. SMUD is partnering with the State of California Department of General Services, California State University Sacramento, and the Los Rios Community College District on this project.

Objectives:

1. deployment of AMI
2. assist recovery of vital data
3. creating a fully automated distribution system for SMUD

Benefits:

This project will link smart meters and home area networks with upstream, automated distribution operations; will optimize distribution system operations to improve system reliability and efficiency; and, will fully enable customers to participate in the electricity market place by accelerating the introduction of dynamic pricing and demand response programs. The project will significantly accelerate and expand the deployment of advanced smart grid technologies throughout the Sacramento region, creating new jobs, preserving existing jobs, reducing customer energy costs, and cutting greenhouse gas emissions.

Title:	Characterization of Wilmington Graben for Large Scale CO_2 Geologic Storage				
Agreement Number:	PIR-10-062	Project Number:	1	Research Stage:	Technology Development
Electricity Funding:	$500,000	Match Funding:	$9,100,604	Natural Gas Funding:	$0
Start Date:	5/14/2011	End Date:	10/31/2014	Technology Topic:	GHG Sequestration
Award Recipient:	Terralog Technologies			End-Market:	Energy Suppliers

Description:

The Pliocene and Miocene Formations in the Wilmington Graben are being characterized and documented through a comprehensive research effort that includes: 1) evaluation of existing two-dimensional and three-dimensional seismic data for the region, with some additional new data acquisition; 2) detailed evaluation of well logs from historical exploration wells in the area, compared with and tied to more extensive onshore well data; 3) drilling, coring, and testing new stratigraphic wells in the graben; 4) development of three-dimensional geologic models, geomechanical models, and CO_2 injection models; 5) comprehensive evaluation of storage capacity, seals, and risk assessment; and, 6) project documentation and interaction with WESTCARB and DOE. The Energy Commission funding is only being used for data evaluation, risk assessment, model development, project documentation, and technology transfer. The expected results for this project will establish and document the potential for more than 50 million tons of CO_2 storage in a high need area.

Objectives:

1. Evaluate existing and newly acquired two-dimensional (2D) and three-dimensional (3D) seismic data for the region
2. Evaluate well logs from historical exploration wells in the area
3. Drill, core, and test two new stratigraphic wells in the Wilmington Graben
4. Develop 3D geologic models, geomechanical models, and CO_2 injection models for the region
5. Comprehensively evaluate target zone storage capacity, seals, and risk assessment
6. Provide detailed review, quantification and documentation of top 20 industrial sources of CO_2 emissions
7. Provide detailed engineering review and analysis of existing and new pipeline and gas storage systems in the Los Angeles Basin
Provide guidance for evaluation of similar subsurface geologic regimes present in other areas of California (i.e., fault-bounded turbidite structures)
9. Contribute data to both California-specific and national CO_2 sequestration investigations and GHG emission reduction efforts

Benefits:

Growing concerns about greenhouse gas emissions and global warming drive an increasing need for power plants and other industrial facilities to significantly reduce CO_2 emissions into the atmosphere. The Los Angeles Basin is home to more than a dozen major power plants and oil refineries that produce more than five million metric tons of CO_2 emissions each year. The Wilmington Graben is an area offshore of Los Angeles that contains more than 5,000 feet of thick Pliocene and Miocene sediments with saline aquifers that may be suitable for geologic storage of CO_2. The current project will provide more data and understanding on the potential for CO_2 geologic storage in the Wilmington Graben to help reduce the area's CO_2 emissions.

Title:	Flow Battery Solution to Smart Grid Renewable Energy Applications				
Agreement Number:	PIR-10-066	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$476,428	Match Funding:	$9,052,139	Natural Gas Funding:	$0
Start Date:	9/1/2011	End Date:	12/31/2015	Technology Topic:	Battery
Award Recipient:	EnerVault Corporation			End-Market:	Ratepayers

Description:

This project demonstrates an iron-chromium redox flow battery system in combination with an intermittent, renewable energy source. The project uses EnerVault's long duration system to reduce demand charges and enhance the performance of a 150kWp AC dual-axis tracking photovoltaic system to power a large 260kW irrigation pump. The demonstration, underway now, will establish the suitability of megawatt-hour scale, long duration energy storage systems to meet the safety, reliability, and cost requirements of distributed energy storage.

Objectives:

1. Demonstrate the commercial viability of EnerVault's novel redox flow battery energy storage system
2. Integrate 250kW / 1MW-hr system with a 150kW AC dual axis photovoltaic system

Benefits:

Establish a safe, reliable cost effective solution for enabling high penetrations of intermittent renewable energy on the utility grid.

Title:	Glendale Water & Power - Marketing. Public Benefits				
Agreement Number:	PIR-10-069	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$1,000,000	Match Funding:	$50,302,105	Natural Gas Funding:	$0
Start Date:	6/1/2011	End Date:	3/31/2015	Technology Topic:	AMI/Smart Meters
Award Recipient:	City of Glendale			End-Market:	Energy Suppliers

Description:

Glendale Water & Power (GWP) is installing 83,000 smart meters with large data storage capabilities and 2-way communications hardware and software. The smart meters will be connected through a wide area network to allow 2-way communications between the utility and each meter. Additionally, the smart meters will possess the capability to communicate with a home area network (HAN) to promote demand response, energy and water conservation, and dynamic pricing options.

Objectives:

1. deploy smart meters
2. create customer interfaces for home area networks (HAN)
3. implement dynamic pricing
4. enable demand response program participation
5. provide information to help customers conserve energy and water

Benefits:

The benefits include reductions in peak demand, increases in energy efficiency, improvements in grid reliability, integration of renewable resources, and economized use of existing transmissions assets.

Title:	Solid State Batteries for Grid-Scale Energy Storage				
Agreement Number:	PIR-11-001	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$600,000	Match Funding:	$11,792,122	Natural Gas Funding:	$0
Start Date:	11/21/2011	End Date:	9/25/2014	Technology Topic:	Battery
Award Recipient:	Seeo Inc.			End-Market:	Ratepayers

Description:

The purpose of this project was for Seeo to deliver the first ever large-scale or grid-scale prototype of a new class of advanced lithium ion rechargeable batteries. The technology would combine unprecedented energy density, lifetime, safety, and cost. The goal was to demonstrate Seeo's entirely new class of lithium-based batteries based on Seeo's proprietary nanostructured polymer electrolyte.

Seeo has successfully scaled up its core polymer technology, and cell technology as part of this project. In addition, a 10 kWh prototype energy storage system was designed and assembled. The energy storage system was tested and demonstrated that it could work with a photovoltaic array for a grid-tied application.

Objectives:

1. Optimize materials to improve cell power and energy capabilities
2. Scale-up materials, cell size and fabrication capacity
3. Build a fully functional prototype demonstration battery pack to meet and surpass Smart Grid requirements
4. Test the demonstration battery pack under simulated grid-tied conditions and gather operating data for analysis
5. Perform Environmental and Economic Impact Analysis
6. Elaborate Business Plan to justify manufacturing & distribution of battery in US & globally for grid-tied energy storage

Benefits:

Seeo scaled up core solid polymer technology and cells from lab-scale to large commercial scale that can be easily transferred to high volume manufacturing. It was demonstrated that the technology works with a grid-tied application such as a photovoltaic array and can store energy generated during the day for use in evening hours. Combining renewable energy sources, such as wind and solar, with energy storage (batteries) provides potential for lowering energy costs for California rate-payers.

Title:	Smart Grid Demonstration Project				
Agreement Number:	PIR-11-009	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$1,000,000	Match Funding:	$119,560,000	Natural Gas Funding:	$0
Start Date:	6/25/2012	End Date:	5/31/2015	Technology Topic:	Total Energy
Award Recipient:	Los Angeles Department of Water & Power			End-Market:	Ratepayers

Description:

This project is to support LADWP's Smart Grid Demonstration Program. Specifically, the project supports the development of the Chatsworth test bed, which will be used to assist in demonstrating demand response, EVs, distribution automation, cyber security, and customer behavior studies.

Objectives:

1. Development of the Chatsworth test bed
2. Demonstrating demand response
3. Demonstrating adoption of electric vehicles and its impact
4. Demonstrating distribution automation
5. Demonstrating next-gen cyber security for the Advanced Metering Infrastructure
6. Demonstrating customer behavior towards Smart Grid

Benefits:

This project will help improve LADWP's grid reliability and support higher penetration of distributed generation resources and electric vehicles.

Title:	SGIG Distribution Infrastructure Substation Upgrades				
Agreement Number:	PIR-11-015	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$149,315	Match Funding:	$2,837,025	Natural Gas Funding:	$0
Start Date:	6/25/2012	End Date:	3/31/2015	Technology Topic:	Distribution
Award Recipient:	Modesto Irrigation District			End-Market:	Energy Suppliers

Description:

MID is implementing a multi-stage Smart Grid Deployment and Installation Project. The project includes three phases. (1) meter purchase and installation in the Mountain House Development: This would complete a full roll out of smart meters that MID began in 2009 for which the utility has already invested $20 million. (2) distribution grid upgrades to improve communication and better control over various aspects of the distribution level grid. (3) customer program development, including customer interface, cost of service and pricing studies, and customer outreach and education.

Objectives:

smart meter purchase and installation - complete a full roll out of smart meters
2. distribution smart grid upgrades to improve communication and control
customer program development, including customer interface, cost of service and pricing studies, and customer outreach and education

Benefits:

Benefits include: optimization of the feeder voltage to minimum allowable levels for end-of-line customers; reduction of feeder losses; deferral of feeder upgrades due to overloads; economized use of capacitors; improved grid reliability; integration of renewable resources; and, improved use of existing transmissions assets.

Title:	Smart Grid High Concentration Solar Photovoltaic Integration				
Agreement Number:	PIR-11-017	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$1,000,000	Match Funding:	$39,735,991	Natural Gas Funding:	$0
Start Date:	6/25/2012	End Date:	3/31/2015	Technology Topic:	AMI/Smart Meters
Award Recipient:	Burbank Water and Power			End-Market:	Energy Suppliers

Description:

The project is demonstrating new smart grid technologies, including Insulated Gate Bipolar Transistors (IGBT) based inverters. This will promote the integration of distributed renewable energy resources into the electric grid, leading to improved reliability and stability, a more diverse generation portfolio, and GHG emission reductions. The system will be installed in the City of Burbank.

Objectives:

1. full-scale smart grid implementation
2. conservation of water and electricity
3. implement distribution automation
4. deploy customer network interfaces
5. deploy electricity storage
6. promote integration of renewable resources

Benefits:

The project demonstrated Smart Grid integration of new technologies that will maximize the advancements made in concentration cells, optics, and tracking systems, and inverters designed to address the technological barriers. Additionally, this project will improve grid reliability, facilitate integration of renewable resources, and improve the use of existing transmission assets.

Title:	Advanced Underground CAES Demonstration Project Using a Saline Porous Rock Formation as the Storage Reservoir				
Agreement Number:	PIR-12-001	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$1,000,000	Match Funding:	$49,000,000	Natural Gas Funding:	$0
Start Date:	11/26/2012	End Date:	3/15/2015	Technology Topic:	Compressed Air
Award Recipient:	Pacific Gas and Electric Company			End-Market:	Energy Suppliers

Description:

The goal of this project is to demonstrate the viability of advanced, compressed air energy storage (CAES) technology utilizing a porous rock formation. This project will establish the costs and benefits of CAES, verify its technical performance, and validate system reliability and durability at a scale that can be readily adapted and replicated around the country.

Objectives:

Verify the technical performance of advanced CASE technology using a porous rock formation as the underground storage reservoir
Integrate intermittent renewable resources by unsing the CAES plant to provide ramping/regulation to steady the power fluctuations from load and intermittent renewable generation
3. Use the CAES plant to provide emergency spinning/non-spinning reserve (synchronous and non-synchronous)
4. Perform Volt-Amperes Reactive (VAR)/votage support

Benefits:

The project is expected to produce measurable benefits such as reduced greenhouse gas emissions, improved grid reliability and flexibility, and lower electric power system costs.

Title:	Demonstration of a Vortex Technology for Wastewater Disinfection with UV Light				
Agreement Number:	500-09-050	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$150,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	8/9/2010	End Date:	2/1/2014	Technology Topic:	Water Quality
Award Recipient:	UC Davis			End-Market:	Ratepayers

Description:

This project designed and developed a vortex reactor for water and wastewater disinfection that improves upon the conventional chemical disinfection treatment. Benefits include lower capital and operating costs, improved energy efficiency, easier maintainability and greater efficiency in disinfecting numerous contaminants.

Objectives:

To develop and quantify the effectiveness of a new wastewater disinfection technology using ultraviolet (UV) light in an operational environment
2. To demonstrate its benefits, efficiency, maintainability, robustness and reliability to the water quality community
3. Refine the original vortex design based on the test program results and demonstrated its benefits to the water quality community
4. Quantify the disinfection efficiency for a range of flow rates for larger-scale applications

Benefits:

Two major California's industries - horticulture and aquaculture - can reap significant economic benefits including lower capital and operating costs, improved energy efficiency, easier maintainability and greater efficiency in disinfecting numerous wastewater contaminants. This new technology could also expand water re-use for agricultural and recreational purposes in small disadvantaged communities.

The success of this project has prompted the University of California to apply for a patent to protect the Intellectual property Rights of this new reactor, and to facilitate its commercialization. A grant was awarded by the University of California Office of the President to facilitate commercializing this reactor. Discussions are also underway with a major manufacturer of UV systems to license the new reactor and two major utilities are considering funding to install the new system at two disadvantaged communities in California.

Title:	Data Center Energy Efficiency Demonstration Projects				
Agreement Number:	500-10-052	Project Number:	14	Research Stage:	Technology Demonstration
Electricity Funding:	$294,545	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	9/1/2011	End Date:	12/31/2014	Technology Topic:	Whole Building
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Ratepayers

Description:

This project will demonstrate various advanced technologies to reduce energy use in data centers and to prepare case studies to document the results.

Objectives:

1. In year one, execute the first demonstration and prepare a data center year one demonstration report
2. In year two, execute the second demonstration and prepare a data center year two demonstration report
3. In year three, execute the third demonstration and prepare a data center year three demonstration report

Benefits:

To accelerate the adoption of energy saving measures in data centers.

Title:	Advancing Process Optimization and Energy Efficiency in the Water Industry				
Agreement Number:	500-10-056	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$425,000	Match Funding:	$425,000	Natural Gas Funding:	$0
Start Date:	6/30/2011	End Date:	3/30/2015	Technology Topic:	Planning
Award Recipient:	Water Research Foundation			End-Market:	Ratepayers

Description:

There are two projects in this contract.
Project 1 is the Optimization of Energy and Water Quality Managment Systems (EWQMS)
EWQMS is software control systems for water and water treatment plants that cover pumps and equipment, and process control systems for pumping cycles, leak detection, pressure differentials and reservoir levels. This project is intended to add the ability to integrate these systems into a facility-wide management system for energy efficiency and GHG emissions reduction. This includes developing and implementing pilot demonstration projects that document energy savings and GHG emissions reductions. $375,000

Project 2 is to develop a roadmap by conducting a workshop of water and wastewater industry professionals the outcome of which is to identify and and prioritize future projects that could be part of IAW future solicitations. $50,000

Objectives:

1. Expand Energy and Water Quality Management System to include a module to measure GHG emissions and do a pilot test
2. Develop a Water/Wastewater energy efficiency related research Roadmap via a workshop with experts in the field

Benefits:

The roadmap will identify and prioritize research, development and demonstration investments over the next five years to achieve energy efficiency gains in water and wastewater treatment facilities in California. This will include transfer of knowledge about energy related trends and issues for water utilities, energy optimization and renewable energy methods, and identification of emerging technologies that hold promise for reducing energy use in this sector.

Title:	Self-Audit of Wastewater Treatment Processes to Achieve Energy Optimization, Phase 2				
Agreement Number:	500-11-003	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$347,914	Match Funding:	$117,500	Natural Gas Funding:	$0
Start Date:	9/1/2011	End Date:	6/30/2014	Technology Topic:	Modeling
Award Recipient:	UC Irvine			End-Market:	Ratepayers

Description:

Complete the development of user-friendly software to allow the auditing of existing wastewater treatment plan operation and evaluation of electrical energy savings measures.

Objectives:

1. Enable users to compare actual energy use with site-specific calculations
2. Identify ways to improve energy efficiency
3. Calculate potential energy savings based on specific performance data
4. Quantify the potential energy savings (kWh/yr.) due to the quantification of energy usage with the software

Benefits:

Users can compare energy use in phases of operations with others to identify potential operations that could be refined/upgraded etc. to achieve energy savings.

Title:	Demonstration of Zinc-Flow Energy Storage System				
Agreement Number:	PIR-10-001	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$394,082	Match Funding:	$113,995	Natural Gas Funding:	$0
Start Date:	9/20/2010	End Date:	3/31/2015	Technology Topic:	Battery
Award Recipient:	Premium Power Corporation			End-Market:	Ratepayers

Description:

Lead-acid battery technology currently dominates the energy storage marketplace and is used in nearly all uninterruptible power supply (UPS) application for backup power needs. This technology works ideally when infrequent and short duration backup power is required. However, lead-acid technology cannot be deeply discharged without adversely affecting the battery's life and performance, it is also unreliable and expensive to maintain. Premium Power's Zinc Flow energy storage technology is designed to operate in peak shaving and load management applications where longer duration discharges and frequent cycling are required. Zinc Flow technology offers 30 years of unlimited cycles, 100% depth of discharge, 70% round trip efficiency and is fully autonomous allowing report operation. This project will provide operational experience as well as measurement and validation of the technical and economic performance of the technology provided by a recognized user and supported by one of California's major utilities.

Objectives:

Provide peak shaving in order to reduce demand charges and lower overall utility bills for the demonstration facility
Shift off-peak power to on-peak periods to assist the utility in load leveling generation resources and lower demonstration facility energy bills to take advantage of time of use (TOU) rates
3. Provide limited backup energy to a specific load circuit in the event of a power outage

Benefits:

Some benefits of this project include utility bill reductions, greater energy management capabilities, and grid operations enhancements through diurnal load shifting.

Title:	CASCADE Clean Energy System for Water and Wastewater				
Agreement Number:	PIR-10-011	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$400,000	Match Funding:	$379,224	Natural Gas Funding:	$0
Start Date:	9/27/2010	End Date:	3/31/2014	Technology Topic:	Water Efficiency
Award Recipient:	Cascade Clean Energy, Inc.			End-Market:	Ratepayers

Description: See Objectives

Wastewater treatment uses 5-7% of U.S. annual electrical output. Yet currently only 1% of U.S. treatment facilities recover energy from wastewater. The CASCADE Clean Energy System project is designed to demonstrate that the results of recovering energy from wastewater using select bacteria to clean wastewater more efficiently than existing processes while simultaneously maximizing recovery of renewable energy (methane, hydrogen or electricity) from wastewater and sludge that was demonstrated at a pilot scale in the laboratory are scalable to a commercially acceptable level.

Objectives:

To demonstrate that the CASCADE methane bioreactor can produce energy from wastewater more efficiently through increased nutrient removal

To demonstrate that this anaerobic digestion system has the potential to reduce hydraulic retention time by 50% through increased substrate utilization

Benefits:

Improved methane production, improved biological oxygen demand reduction, improved chemical oxygen demand reduction and reduced hydraulic retention time.

Title:	Supercritical CO_2 Cleaning and Sterilization of Commercial / Industrial Textile				
Agreement Number:	PIR-10-017	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$396,200	Match Funding:	$200,000	Natural Gas Funding:	$0
Start Date:	10/11/2010	End Date:	3/11/2014	Technology Topic:	Other
Award Recipient:	CO2Nexus Inc.			End-Market:	Ratepayers

Description: Build the first commercial super-critical carbon dioxide textile cleaning machine

Commercial / industrial laundry has long been one of the major water consumers and uses billions of gallons of potable water each year. While the industry has implemented water efficiency measures, water use is still significant. CO2Nexus has developed a commercial prototype supercritical carbon dioxide-based laundry system for industrial/commercial laundry facilities that will reduce water consumption and significantly reduce energy usage through the elimination of the associated dryers. In order for market acceptance, the technical and commercial feasibility of a supercritical-carbon dioxide textile cleaning and disinfection machine must be demonstrated with independent verification of the energy and water savings.

Objectives:

1. Design and build a commercial scale dense phase CO_2 textile cleaning /sterilization machine
2. Implement and optimize this machine for cleaning in an industrial clean room laundry facility
3. Measure and validate the technical cleaning (including sterilization) and economical performance of this machine. This includes cleaning performance; cycle time; workflow efficiency; energy and water consumption; and overall machine operation and reliability.
4. Determine the real world operation and cost comparisons between water-based and CO_2-based textile cleaning in an industrial setting
5. Increase consumer awareness of CO_2 textile cleaning
6. Reduce greenhouse gas (GHG) emissions, reduce effluent water from commercial and industrial laundry, and provide a cost saving technology to the public

Benefits:

CO2Nexus' Tersus™ Cleanroom Solutions demonstrated improved operational efficiency (50 percent higher throughput efficiency), lower operational cost (50 percent lower operational expenses) and significant utility savings compared to traditional water-based cleaning methods employed in cleanroom laundries. An estimated $335,000 in annual utility related expenses could be saved by Aramark's Los Angeles facility if CO_2-based garment cleaning fully replaced water-based washing.

Title:	High Efficiency Server Fans				
Agreement Number:	PIR-10-020	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$287,757	Match Funding:	$96,188	Natural Gas Funding:	$0
Start Date:	3/1/2011	End Date:	9/1/2014	Technology Topic:	Other
Award Recipient:	PAX Scientific, Inc.			End-Market:	Ratepayers

Description:

Apply a novel biomimicry technology based on the principles of fluid movement to the development of cooling fans used in servers.

Objectives:

1. Select and baseline server
2. Iterate CFD & meshing parameters to establish simulation set-up
3. Design fan
4. Prepare samples
5. Compare power consumption monitoring & analysis
6. Transfer technology

Benefits:

The current PAX V1 fan design demonstrated a 35-45% lowering in power usage for matched cooling compared with the best-in-class Nidec and Delta fans currently shipping with the server. The twelve fans targeted initially used about 700W of power at full duty cycle, while the PAX fans use less than 400W.

Switching to PAX fans in the server will have a significant reduction in wasted energy, which will reduce operational cost and GHG emissions. Additionally, the PAX fans are the same cost to manufacture and fit into the existing architecture.

Title:	Novel Hydrodynamic Separation Technology for Wastewater Treatment				
Agreement Number:	PIR-11-006	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$1,001,899	Match Funding:	$380,817	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	3/30/2015	Technology Topic:	Other
Award Recipient:	Palo Alto Research Center, Incorporated			End-Market:	Ratepayers

Description:

Demonstration of the Hydrodynamic Separation (HDS) Technology to significantly reduce the energy footprint of a waste water treatment plant and to protect the environment from sewer pollution during storm surges.

Objectives:

1. To demonstrate that an HDS pilot system can continuously perform in a real wastewater plant
2. To demonstrate the HDS system can achieve at least 70% removal of solids on a weekly average basis
3. To demonstrate a net energy saving through both reduced energy usage in wastewater treatment and increased biogas production in digesters

Benefits:

This project aims to achieve a low energy consuming alternative for waste water treatment plant's (WWTP) influent clarification and to counter storm surges by demonstrating the HDS technology as a superior technology for wastewater suspended solids removal.
The benefits are:

1. Provide a lower energy-consuming alternative for solids recovery and to reduce the load on secondary processes
2. Generate biogas in the digestion of extra organic solids and thus reduce natural gas consumption
3. Enable plants to have a low-energy backup capacity or standby storm surge measure
4. Allow an option for increases in process capacity by removing suspended solids that need to be treated

Title:	Low-Cost, Scalable, Fast Demand Response for Municipal Wastewater and Recycling Facilities				
Agreement Number:	PIR-11-007	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$1,199,544	Match Funding:	$603,100	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Technology Facilitation
Award Recipient:	AutoGrid Systems, Inc.			End-Market:	Ratepayers

Description:

This project will demonstrate AutoGrid's Demand Response Optimization and Management System (DROMS) to allow the demonstration site to broadly engage in traditional peak capacity management type DR as well as new fast responding ancillary services programs in an integrated and optimized manner.

Objectives:

1. Remove barriers to the adoption of demand response through the integration of a cloud-based, open standards system that eliminates large upfront IT expense and can scale at a cost per user
2. Improve the optimization machine learning algorithms to optimize energy use for industrial facilities
3. Greatly improve the predictive ability of the available energy resources and reduce marginal procurement needs through the integration of sophisticated modeling and time-series based analytics engines

Benefits:

The project aims to provide quantitative and measurable benefits in a number of areas:

- 10% reduction in peak demand at the industrial sites
- 10% reduction in demand charges during the summer months at the industrial sites
- Identification and testing of telemetry equipment capable of providing ancillary services to the grid at less than $10,000 per site
- Demonstrate a payback period of 24-months or less for the facility for the cost of equipment

Title:	Peak Shaving with Flywheel Energy Storage Device				
Agreement Number:	PIR-11-010	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,800,000	Match Funding:	$800,000	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	6/30/2015	Technology Topic:	Storage
Award Recipient:	Berkeley Energy Sciences Corporation			End-Market:	Industrial

Description:

This project will demonstrate and verify the performance of Berkeley Energy Science Corporation's (BESC) novel flywheel energy storage technology. The system will be used as a means of reducing demand and usage charges and will double as an uninterruptable power supply.

Objectives:

1. Develop a multi-hour flywheel energy storage system with high round-trip efficiency and low coasting losses
2. Test and demonstrate the performance of the multi-hour flywheel system
3. Develop a manufacturing plan to achieve commercial cost targets

Benefits:

This demonstration of two 40-kWh flywheel energy storage devices will create an extensive data set to enable accurate characterization of system efficiency, power, kWh load shift capability, and total cost savings. BESC's flywheel storage proposal represents a compelling opportunity because BESC is the first to use flywheel energy storage for extensive load shifting. BESC flywheels will be significantly cheaper than any existing storage technology with the full production delivered price projected to be below $225/kWh. The current market for energy storage is very large and expected to grow rapidly with the increased adoption of renewable energy, and furthermore new markets are expected to emerge as energy storage becomes economically viable on a large scale.

Title:	Demonstration of i50 Decentralized Wastewater Treatment/Water Recycling				
Agreement Number:	PIR-11-011	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$750,000	Match Funding:	$250,000	Natural Gas Funding:	$0
Start Date:	6/30/2012	End Date:	3/30/2015	Technology Topic:	Water Efficiency
Award Recipient:	Great Circle Industries, Inc.			End-Market:	Policymakers/Regulators

Description:

This research will collect the body of data needed to gain Title 22 regulatory approval from the California Dept. of Health (CDHP) for water reuse from the Great Circle Industries effluent water product.

Objectives:

1. To collect that body of data needed to gain Title 22 regulatory approval from the CDPH
2. To measure and analyze energy and power consumption vs. effluent flow with calculation of energy consumption
3. To demonstrate irrigation performance with sample planting of crops
4. To find a prospective beta site that will use the technology in or near the service area of the Dublin San Ramon Services District

Benefits:

The subject i50 modular wastewater treatment system treats and recycles municipal sewer water into irrigation water. Most (about 80%) of the drinking water in California is used for irrigation. By recycling wastewater into irrigation water in an energy efficient manner, energy is saved by not needing to transport water from faraway sources. The decentralized treatment system saves water, energy and valuable plant nutrients.

Title:	Primary Effluent Filtration as an Intermediary Wastewater Treatment Step				
Agreement Number:	PIR-11-018	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$1,418,800	Match Funding:	$568,800	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Wastewater
Award Recipient:	Kennedy/Jenks Consultants, Inc.			End-Market:	Ratepayers

Description:

This project is a demonstration of a Primary Effluent Filtration (PEF) system that reduces the organic content of wastewater after the primary clarification step and before the secondary aeration step. Filtering the wastewater in this way reduces the aeration power requirements, increases treatment capacity, and increases the recovery of energy through increased anaerobic digester gas energy production.

Objectives: Precise prediction of secondary treatment capacity increase

1. Demonstrate that primary clarifier effluent filtration is commercially viable and advantageous as an intermediary treatment step to achieve significant energy savings at waste water treatment plants.

Benefits:

There are over 800 WWTPs in California, and approximately 300 of them have a capacity of at least 1 million gallons per day (mgd) and secondary treatment (mainly activated sludge process), making these plants suitable for this emerging technology. These 300 WWTPs have a combined capacity of over 4,000 mgd. Assuming an ultimate 60% implementation of the technology, it is estimated that the annual energy savings is $48 million assuming a load reduction of 50 MW and total construction cost savings in California will be approximately $450,000,000. These cost savings will translate into lower operating cost for public agencies that are supported by tax payers, and possibly lower sewer rates and connection fees for CA ratepayers. The overall operational efficiency of the WWTPs will also increase due to reduced aeration power requirements and increased gas energy production, with greenhouse emissions being reduced per unit of effluent treated.

Title:	Full-Scale Demonstration of an Innovative Electrodialysis Technology for Zero Liquid Discharge Desalination				
Agreement Number:	PIR-11-020	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$799,860	Match Funding:	$249,000	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Desalination
Award Recipient:	Black & Veatch			End-Market:	Policymakers/ Regulators

Description:

The purpose of this project was to evaluate a full-scale electrodialysis metathesis (EDM) stack for treatment of concentrate from a desalination plant. The EDM stack was tested at the Beverly Hills Water Treatment Facility treating concentrate from their reverse osmosis (RO) membranes. The EDM technology will reduce the cost for management of desalination concentrate in California.

Objectives:

1. Demonstrate EDM treatment of RO concentrate
2. Determine energy requirements and savings for EDM treatment of RO concentrate

Benefits:

The project demonstrated the use of EDM to treat RO concentrate at approximately 50 percent of the energy and cost of the established technology, thermal desalination. Furthermore, the project demonstrated recovery of the salts in concentrate to avoid landfill disposal of salts removed during the desalination process.

Title:	Demonstration of full scale Biomass Blending and Densification System (BBADS) densification system				
Agreement Number:	PIR-11-021	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,390,941	Match Funding:	$481,391	Natural Gas Funding:	$0
Start Date:	6/29/2012	End Date:	3/31/2015	Technology Topic:	Other
Award Recipient:	Altex Technologies Corporation			End-Market:	Ratepayers

Description: This research will address the industrial energy efficiency area specifically related to reducing power needs of biomass densification equipment.

Objectives:

1. To develop and demonstrate a full scale Biomass Densification System that will have a processing capacity of 15,000 tons/year that can density biomass to 25 lb/cf
2. To show reduction of overall cost to less than 50% over existing densification units
3. To show reduction of overall energy use to less than 50% over existing densification units

Benefits:

Distributors must control transport costs to markets. This requires that the low density of 3 to 5lb/cf of loose hay be increased to 35lb/cf for most economical transport in containers from the farm to overseas sites. Current methods of densification, including cubing and double baling, require substantial electric power of $3.00/ton of densified material. Furthermore, the densities achieved are only 20 to 25 lb/cf, respectively.

Through development efforts by Altex, the BBADS biomass densification process has been shown to create biomass logs with a density of 30 to 60lb/cf, depending on materials and equipment settings. Therefore, BBADS can achieve the ideal transport density of 35lb/cf. Most importantly, the process achieves the density of an electric power cost of $1.16/ton, which about 60%, lower than conventional cubing and double baling.

Title:	Economic Benefits of Firm Concentrated PV Energy for the Grid				
Agreement Number:	PIR-11-031	Project Number:	1	Research Stage:	Technology Development
Electricity Funding:	$1,392,464	Match Funding:	$434,000	Natural Gas Funding:	$0
Start Date:	6/1/2013	End Date:	3/31/2016	Technology Topic:	Other
Award Recipient:	Maxwell Technologies			End-Market:	Energy Suppliers

Description:

The goal of this program is to demonstrate the ability of a concentrated photovoltaics (CPV)-ultracapacitor interface to reduce the requirements for real-time utility power regulation by increasing CPV power output stability. Utility power regulation is the rapid increase or decrease of power generation generally using gas turbines in response to fluctuations in grid demand or fluctuations in power output from renewable generation . From an economic perspective, the project will directly translate the power stability gained into benefits for industrial ratepayers.

Objectives:

1. Determine the optimized hardware configuration for a unified CPV-ultracapacitor system via modeling and system design
2. Measure the CPV utilization efficiency gained by testing and measurement at the small (28kW) and large scale (250kW)
3. Quantify cost savings related to integration of an ultracapacitor bank, and 4) Quantify the benefits to industrial California ratepayers

Benefits:

The ultracapacitor technology in this project can be directly applied to wind and PV generation, and can therefore have considerable impact in the intended marketplace. The ultracapacitor energy storage system being developed by this program enables the effective, large-scale integration of naturally variable renewable energy sources into the grid by smoothing and firming their output. This project will demonstrate the positive benefit of ultracapacitors on the economics of a grid-based renewable energy system and their impact on the practical ability to integrate a large percentage of renewable energy sources on a grid.

Title:	Bay Area Biosolids to Energy				
Agreement Number:	500-10-034	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$999,924	Match Funding:	$3,739,000	Natural Gas Funding:	$0
Start Date:	5/9/2011	End Date:	3/31/2015	Technology Topic:	Biomass
Award Recipient:	Delta Diablo Sanitation District			End-Market:	Ratepayers

Description:

Researchers from Chemergy, Inc. (Miami, Florida), Lawrence Livermore National Laboratory (Livermore, California), and Delta Diablo (Antioch, California), in coordination with the Bay Area Biosolids to Energy (BAB2E) Coalition, have joined together to demonstrate an innovative bioenergy technology (Chemergy's HyBrTecTM concept, which grows out of early work by Rockwell in the 1980s) that converts wastewater treatment plant byproducts into renewable hydrogen fuel. The hydrogen can be used to produce electricity for stationary power or serve as a fuel in hydrogen fuel cell vehicles. The $1.75 million project, which is co-funded by the California Energy Commission and private investment, will demonstrate an integrated system on a limited scale at the Delta Diablo facility. The demonstration is expected to begin in December 2014 and run through at least March 2015.

Objectives:

1. Design and procure components for an electrochemical conversion plant to process biosolids
2. Demonstrate reliable conversion of biosolids to hydrogen gas for electrical power production or fuel alternate
3. Demonstrate electrical power generation using fuel generated by conversion of biosolids
4. Test and evaluate the conversion system
5. Verify the conversion efficiency of biosolids to hydrogen
6. Establish the treatment procedures and confirm bromine recovery
7. Confirm preliminary cost for hydrogen production via this process
8. Prepare an economic analysis of the system
9. Complete a preliminary permitting assessment for regulatory and safety issues
10. Make available technical data for use by agencies interested in developing a biosolids to energy program

Benefits:

This project will demonstrate a system for electrochemically converting biosolids to energy. Successful implementation of this technology will maximize the energy production from the biosolids while meeting California's environmental standards including air emission limits. It will allow widespread implementation at wastewater treatment facilities across California, resulting in energy savings and GHG emission reduction as a result of reduced trucking of biosolids. Fully utilizing this renewable biomass resource to produce energy will reduce reliance on petroleum projects, moving California toward meeting its renewable energy goals.

Title:	Application of a Solar Forecasting System to Utility Sized PV Plants on a Spectrum of Timescales				
Agreement Number:	500-10-057	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$442,136	Match Funding:	$145,519	Natural Gas Funding:	$0
Start Date:	6/30/2011	End Date:	6/30/2014	Technology Topic:	Solar PV
Award Recipient:	AWS Truepower, LLC			End-Market:	Energy Suppliers

Description:

The project configured and demonstrated a set of solar forecasting tools for California that provides the best possible forecast of solar power production on time scales ranging from a few minutes to several days ahead. The forecasting system served as a proof of concept for high-fidelity forecasting at utility-scale PV plants. It was demonstrated at Sempra's Copper Mountain photovoltaic facility near Henderson, Nevada, and operated for a period of one year to establish performance and validation metrics.

Objectives:

1. Configure, demonstrate, validate, and integrate a set of solar forecasting tools for California that provides the highest possible performance for frequently updated forecasts of solar power production on multiple timescales ranging from a few minutes to several days ahead

Benefits:

The knowledge gained in this project will be directly used to improve the performance of the operational hour-ahead and day-ahead solar power generation forecasts that AWS Truepower provides to CAISO. Many of the component methods used in this project are already being employed in the ensemble forecast system used for the CAISO application. The results obtained from this project will provide the basis for improvements in two areas: (1) refinements to the component methods already being employed in the CAISO forecast production with a focus on an improved model output statistics procedure to correct system errors in the numerical weather prediction forecasts; and, (2) a more optimal way to create the composite forecast from the individual ensemble members. It also provides a foundation for further research to extract additional forecast value from both of these approaches.

Title:	Grid-Saver Fast Energy Storage Demonstration				
Agreement Number:	500-10-058	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$2,000,000	Match Funding:	$520,004	Natural Gas Funding:	$0
Start Date:	6/30/2011	End Date:	12/31/2014	Technology Topic:	Battery
Award Recipient:	Transportation Power, Inc.			End-Market:	Ratepayers

Description:

The Grid-Saver™ Fast Energy Storage Demonstration ("Grid-Saver™/FESD") program addresses the problem of integrating utility-scale renewable energy (USRE) projects into the electric power grid. The prevalent form of battery energy storage, phased into use over the past decade, relies on sodium sulfur batteries, which are expensive and present potential safety hazards if the sodium is exposed to water. The Grid-Saver™ approach is to offer a new solution based on modular building blocks that can be produced at low cost and integrated using advanced systems integration and control methods. The Grid-Saver™/FESD program will demonstrate the viability of this concept by building, testing, and deploying a 5 megawatt (MW) fast energy system comprised of interchangeable lithium battery modules and high-power inverter modules. This modular approach will reduce manufacturing costs and simplify maintenance, while also enabling different size Grid-Saver™ systems to be delivered to meet varying requirements. The challenge is to deliver integrated Grid-Saver™ systems for a cost of less than 50 cents/watt, which is at least 5-6 times lower than the cost of competing sodium sulfur battery systems.

Objectives:

1. Perform initial testing of the prototype Grid-Saver system in a laboratory setting to validate the proof of concept
2. Establish a foundation for successful commercialization of the Grid-Saver? technology through technology transfer activities and production planning
3. Installed cost per watt of peak power delivered at least four times lower than the cost of competing energy storage systems using sodium sulfur batteries
4. Delivery of 5 MW of peak power and approximately 1 megawatt hour (MWh) of total energy in a substantially smaller package than competing grid energy storage technologies
5. Complete a cost-benefit analysis to validate the benefits of specific design concepts such as use of a mass-produced "common battery module" consisting of lower cost lithium cells, operation at higher voltages, and utilization of advanced battery management techniques
6. Build a prototype Grid-Saver system within tight budgetary constraints, subject to analytical confirmation of substantial cost savings and technical feasibility
7. Scalability to systems capable of providing tens of megawatts of peak power and/or tens of MWh's of storage capacity
8. Perform the analyses and trade studies required to optimize a Grid-Saver system designed to meet the goals
9. Minimum 50% improvement in response time to address system faults

Benefits:

The improved cost, flexibility and availability of energy storage can play important role in helping the state achieve its renewable energy goal of 33% by 2020. Adoption of lower-cost energy storage technology will translate to reduced cost of additional generating capacity and lower utility rates. Market penetration of the technology will also spur employment benefits, currently estimated at 800 person-years for 10% market penetration.

Title:	Utility Scale Solar Forecasting, Analysis and Modeling				
Agreement Number:	500-10-060	Project Number:	1	Research Stage:	Road Mapping
Electricity Funding:	$450,000	Match Funding:	$140,217	Natural Gas Funding:	$0
Start Date:	6/30/2011	End Date:	3/30/2015	Technology Topic:	Solar PV
Award Recipient:	EnerNex, LLC			End-Market:	Energy Suppliers

Description:

This proposed project will develop a model partnership agreement, standardized technology evaluation criteria, and replicable processes that can be tested in a multi-jurisdictional setting for creating a plan to guide expansion and integration of local renewable energy technologies in environmentally sensitive communities; explore the capability of coordinating energy loads and resources of water and other infrastructure systems with electric utility distribution grid operations among historically independent operators; and, develop a strategic, integrated renewable energy plan for South Tahoe Public Utility District (STPUD)/Liberty Utilities region.

Objectives:

1. Develop a short-term forecasting tool for predicting solar plant output in the seconds to hours-ahead timeframe
2. Demonstrate and validate the solar forecasting tool at several locations in Southern California
3. Develop long term system forecasting models to predict the system effects of high solar penetration

Benefits:

Benefits from this project include cost reduction and reduced environmental impacts to electricity rate payers, reliability improvement and support increased market high solar penetration.

Title:	Renewable Energy Resource, Technology and Economic Assessments				
Agreement Number:	500-11-020	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$2,000,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/15/2012	End Date:	3/31/2015	Technology Topic:	Renewables
Award Recipient:	The Regents of the University of California, Davis			End-Market:	Ratepayers

Description:

The purpose of this agreement is to update and refine existing renewable energy resource and technology assessments and databases needed by stakeholders; provide for regional renewable energy assessments that are integrated, comparative and multi-dimensional; and address the complex issues and renewable energy development and integration data needs arising from efforts to increase California's use of its extensive renewable energy resources.

Objectives:

1. Update and refine existing renewable energy resource and technology assessments and databases needed by stakeholders
2. Provide for renewable energy assessments that are integrated, comparative, and multi-dimensional
3. Address the complex issues and renewable energy development and integration data needs arising from efforts to greatly increase California's use of its extensive renewable energy resources

Benefits:

The results of this research are intended to provide California policy-makers, utilities, industries, state and local agencies, and project developers with current information on the major renewable energy resources, including biomass, geothermal, solar, wind, and small hydropower. It also includes technical and economic analysis of the related conversion technologies to help the state to reach established renewable energy goals, take advantage of renewable energy deployment opportunities, and address potential development challenges that may arise.

Title:	Piloting The Integration and Utilization of Renewables to Achieve a Flexible and secure energy Infrastructure				
Agreement Number:	PIR-08-033	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$948,903	Match Funding:	$948,903	Natural Gas Funding:	$0
Start Date:	7/29/2009	End Date:	3/31/2014	Technology Topic:	Renewables
Award Recipient:	Advanced Power and Energy Program - UC Irvine			End-Market:	Ratepayers

Description:

This project has examined key challenges to achieving high penetrations of renewables onto California's grid by investigating the effective use of distributed energy resources, including solar, wind and biomass for electricity, heating and transportation. The UC Irvine campus served as the model community.

Objectives:

1. Developed the Holistic Grid Resource Integration and Deployment (HiGRID) tool to perform dynamic analyses to integrate a wide array of technologies
2. Developed flexible circuits for interconnection of distributed energy resources
3. Dynamic price signals were used to evaluate and dispatch distributed energy resources
4. Demonstrated, and monitored distributed solar PV systems

Benefits:

This project advances California's energy policy goals of promoting distributed renewable energy.

Title:	West Village Renewable-Based Energy Secure Community				
Agreement Number:	PIR-08-035	Project Number:	1	Research Stage:	Technology Development
Electricity Funding:	$1,994,322	Match Funding:	$1,999,095	Natural Gas Funding:	$0
Start Date:	7/29/2009	End Date:	3/31/2014	Technology Topic:	Zero Net Energy Buildings
Award Recipient:	UC Davis			End-Market:	Ratepayers

Description:

West Village (WV) aims to be a Zero Net Energy (ZNE) community by satisfying its annual electricity and gas demand through on-site renewable resources through the integration of a diverse array of distributed energy resources (DER) using commercially available and state-of-the-art technologies. The technical complexity challenges facing intelligent energy asset optimization at a community level is very costly for any single market stakeholder to take on. Further, the envisioned energy infrastructure required at WV requires a significant upfront investment in the horizontal and vertical build out of the community.

West Village will be a mixed-use housing community on the University of California, Davis campus that will provide 3,000 residents with affordable, reliable, and secure energy. It will be a model for future communities and help accelerate the adoption and use of scalable renewable energy systems in California.

Objectives:

1. Evaluate deep energy conservation measure.
2. Determine the energy requirements of the community.
3.Understand the likely increasing demand for plug-in vehicles.
4. Evaluate renewable energy options
5. Evaluate multiple physical design models.
6. Select the current approach to ZNE.
7. Understand the financial and regulatory incentives and barriers to the ZNE goal.
8. Recommend methods for advancing ZNE to other communities.

Benefits:

The West Village project allowed the UC Davis team to evaluate policy, regulatory, and technological issues associated with ZNE construction in a large real-world project. These evaluation results are consolidated and available to disseminate to, and use by, parties interested in ZNE construction. Prior to the West Village project, an information source of this type did not exist for teams considering ZNE construction. UC Davis also worked with Davis Energy Group to create an on-line ZNE Community Assessment Feasibility Tool to provide a starting point for public and private sector stakeholders as they consider ZNE feasibility for community-scale projects they are working to develop. While the on-line ZNE Community Assessment Feasibility Tool will provide direct initial benefit to users who are considering ZNE (and technological approaches and best practices) for their community projects, it is also an investment.

Title:	CERTS Smart Grid Demonstration with Renewables and large-Scale Energy Storage Integrated at Santa Rita Jail, Alameda County, California				
Agreement Number:	PIR-08-039	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$1,983,555	Match Funding:	$2,279,888	Natural Gas Funding:	$0
Start Date:	7/1/2009	End Date:	3/31/2014	Technology Topic:	Renewables/DG
Award Recipient:	County of Alameda			End-Market:	Ratepayers

Description:

This project at Santa Rita Jail will create a real-life working model for renewable energy integration. It is a smart grid demonstration for wind, solar thermal and large-scale energy storage integration.

The project will demonstrate at the jail plug and play characteristics to integrate the new battery system with the existing power conditioning system so that electricity demand during summer peak is decreased to zero. They will establish the potential to export energy and reduce congestion and reliability issues on the local distribution grid by up to 15 percent reduction on the feeder circuit (peak load). The Jail's energy efficiency initiatives remain in place as the researchers continue working toward energy independence and high system reliability in a very high-demanding 24/7 community with a large 4500-inmate capacity.

Objectives:

1. Demonstrate commercial implementation of a CERTS Smartgrid combined with renewables and large-scale distributed energy storage for communities.
2. Reduce peak load of utility distribution feeder by increasing utilization of significant and diverse distributed energy resources to intelligently supply peak power.
3. Improve grid reliability by providing dispatchable renewable energy and other ancillary services to support electric distribution systems.
4. Increase grid efficiency and security through the development of monitoring, diagnostic, and automation capabilities, and research of communications and control technologies.

Benefits:

The Santa Rita Jail's onsite microgrid is now operational. It includes large scale battery storage system integrated with new wind , new solar thermal systems, and the existing systems. The islanding capability has been demonstrated in several successful tests. Many communities will learn from the commercial implementation of this Smartgrid.

Title:	El Dorado County Water Systems Energy Generation, Storage, Efficiency, Demand Management & grid Support Project				
Agreement Number:	PIR-08-040	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$197,950	Match Funding:	$73,069	Natural Gas Funding:	$0
Start Date:	7/29/2009	End Date:	3/31/2014	Technology Topic:	Renewables/DG
Award Recipient:	El Dorado Irrigation District			End-Market:	Ratepayers

Description:

Water conveyance, water treatment, and hydroelectric generating systems are technologically mature. Pumps, storage facilities, and hydropower equipment are durable and proven, and most California water systems are very similar in design and operation. Some recent technological developments, such as variable speed pumps as turbine units with regenerative power converters, hold promise for adding generation to existing water systems with highly variable flows, such as potable water, treatment plant and recycled water distribution systems. However, most systems still operate with limited regard to energy efficiency or use or the demands on the electric grid. Considerable potential energy is lost, and new peaking gravity-based energy systems remains largely unexplored

Objectives:

The project objective is to identify cost effective and operationally feasible measures to integrate energy management and generation into water management systems to most efficiently support the electric utility grid.

Benefits:

Water purveyors interested in increasing the energy efficiency of their system can use the methods and actions developed under this project to evaluate cost effective and operationally feasible types of renewable energy and energy management strategies in their systems and take advantage of lessons learned from feasibility evaluations to analyze their systems.

Title:	Biogas Fuelled HCCI Power Generation System for Distributed Generation				
Agreement Number:	PIR-08-042	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$300,000	Match Funding:	$300,848	Natural Gas Funding:	$0
Start Date:	7/29/2009	End Date:	3/31/2014	Technology Topic:	Biogas
Award Recipient:	Makel Engineering, Inc.			End-Market:	Ratepayers

Description:

The purpose of this project is to develop a biogas fueled Homogeneous Charge Compression Ignition (HCCI) power generation system capable of producing at least 200 kW while still maintaining emissions levels consistent with California Air Resources Board (ARB) 2007 emission standards and AB 32. This project would fund the next phase of Makel Engineering's efforts towards the development of HCCI technology as the model community.

Objectives:

1. Generate greater than 100 kW power by using HCCI technology
2. Achieve greater than 30% brake thermal efficiency
3. Meeting or exceeding CARB 2013 target for NOx <0.07lb/Mweh
4. Meeting or exceeding CARB 2013 target for CO <0.10 lb/Mweh
5. Capital Cost < $2,000/kW
6. Achieve a levelized cost of electricty < $0.14

Benefits:

By developing a technology that enables low cost, highly efficient, and low emissions operation of reciprocating engines on biogas, the project will provide immediate and long term beneficial impacts in the environment and the economy. Widespread use of the technology will help improve the air quality by reducing NOx emissions that contribute to smog formation and reducing release to the atmosphere of GHG-potent methane biogas; reduce operation costs by reducing the cost of electricity while increasing revenue for end users; and improve facility environment and productivity through other beneficial uses of digested solids and effluent liquid by-products.

Title:	High Solar PV Penetration Modeling				
Agreement Number:	PIR-10-003	Project Number:	1	Research Stage:	Technology Development
Electricity Funding:	$500,000	Match Funding:	$1,932,579	Natural Gas Funding:	$0
Start Date:	12/6/2010	End Date:	2/6/2015	Technology Topic:	Generation Forecasting
Award Recipient:	UC San Diego			End-Market:	Energy Suppliers

Description:

The project will develop advanced modeling tools and electric power control strategies to optimize electric power value and remove or reduce the impact of PV-sourced electricity on existing microgrids and the smart grid. Factors to be modeled and evaluated include monitoring of micro-climate effects and sky imaging systems to enable 1-hour-ahead PV-sourced electric power output forecasting in conjunction with a utility's dynamic price signals.

Objectives:

1. Achieve greater than twenty percent reduction in feeder peak load
2. Demonstrating the capability of Volt-Amps-Reactive (VAr) electric power management
3. Develop and demonstrate a strategy for information integration focused on security and system architecture
4. Demonstrate the capability to use automated distribution control to island in response to system problems
5. Developing information/tools addressing the impact of multiple DER technologies

Benefits:

The project developed modeling tools for high penetration scenarios of photovoltaics (PV) on a distribution feeder system for the power system planning process and operations in order to sustain or accelerate high penetrations of PV for grid-tied solar energy systems.

This package provides any user the ability to assess maximum loading of solar PV on a distribution feeder (10% to 50% of the feeder's peak load demand) based upon power flow, short circuit and transient stability analyses and adherence to power system reliability indices. These tools are open source and available for utilities and planners at the DOE High Solar Penetration Portal.

Title:	SMUD's Smart Grid Pilot at Anatolia				
Agreement Number:	PIR-10-004	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$500,000	Match Funding:	$6,016,174	Natural Gas Funding:	$0
Start Date:	6/30/2011	End Date:	3/31/2015	Technology Topic:	Storage
Award Recipient:	Sacramento Municipal Utility District			End-Market:	Energy Suppliers

Description:

This project is evaluating the value of advanced metering infrastructure, PV, and storage for homes with advanced metering infrastructure and PV in combination with three storage scenarios: 1) no storage, 2) home-based storage, 3) community-based storage. The data collected by SMUD will be analyzed and made available in a final project report for assessing the performance and market impacts of these options. The project includes assessment of hardware performance, a benefits framework for rooftop PV with distributed storage, and evaluation of different operating scenarios, and the impacts of different technology configurations and pricing mechanisms on customer behavior.

Objectives:

1. Deploy distributed energy storage
2. Install communications so that the energy storage can be monitored and controlled
3. Install a Utility portal that will allow the recipient to monitor PV output, energy storage, and customer loads, as well as coordinate the resources at a system aggregate level, or more granularly at the substation, feeder, or individual residence level
4. Deploy a Customer portal that will allow consumers to monitor their energy usage, PV output, and energy storage in real-time. In addition, consumers will receive energy conservation tips and other educational tools to help them change their energy use patterns.
5. Determine pricing signals (sent via the Customer portal) that will change the energy usage behaviors of customers
6. Determine if customers who have PV and energy storage manage their energy usage differently when compared to those that do not.
7. Control a PV/energy storage inverter with a smart meter from the recipient's Automated Meter Infrastructure (AMI) deployment
8. Develop a functional specification for a smart meter/inverter interface that would enable management of distributed PV/storage system with AMI, and help to build a strategy for integrating energy storage and PV that can be replicated throughout the recipient's service territory and utility industry as a whole.

Benefits:

The project has yielded some valuable results and conclusions that can benefit similar projects in the future. Key takeways from this study include:

• Distributed energy storage can help manage high penetrations of PV by controlling voltage, managing reverse power flow (reducing ramping), and shifting load.

• Distributed energy storage can add value for SMUD and its customers with benefits of $88/kW to $215/kW for customer-sited and $67/kW to $176/kW for transformer-sited distributed energy storage.

• The impact of PV on the distribution feeder was low – Even though almost all of the 300 homes in the neighborhood had solar PV, SMUD did not find issues at the substation or feeder level.

• A smart meter can be used to control a PV inverter, and most of the necessary protocols are already in place to facilitate this.

• Business models for using distributed PV and energy storage are still in the early phases.

Title:	Technologies for extracting valuable metals and compounds from geothermal fluids				
Agreement Number:	PIR-10-059	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$380,000	Match Funding:	$6,280,682	Natural Gas Funding:	$0
Start Date:	6/30/2011	End Date:	3/31/2014	Technology Topic:	Geothermal
Award Recipient:	Simbol, Inc.			End-Market:	Innovators

Description:

This project developed methods for extracting minerals primarily lithium from hypersaline brines typical of geothermal systems in the Imperial Valley of California. The goal was to convert extracted minerals to products such as lithium carbonate and lithium hydroxide. If found viable, the mineral extraction and conversion process will be tested at a pilot scale using post-power production geothermal brine with the intent of further developing and demonstrating the key steps needed to produce lithium products, in particular, battery grade lithium carbonate, from lithium chloride extracted from geothermal brine. Commercial sales of these products are expected to provide additional revenue streams to geothermal operators.

Objectives:

1. Demonstrate new technologies for extracting lithium using geothermal brines in California
2. Test and validate the extraction technologies and processes at a pilot scale using live geothermal brines
3. In the pilot project convert Lithium to lithium carbonate and lithium hydroxide
4. Produce high purity battery grade lithium carbonate

Benefits:

Hundreds of millions of dollars worth of strategic minerals, such as lithium, manganese and potassium flow annually through geothermal power plants without being captured. This project will utilize that brine to produce high purity battery grade lithium carbonate products. This will generate revenues from tax of these saleable products that are critical to the manufacturing of batteries used in electric vehicles and battery storage technologies. Jobs are also created directly at the lithium production plant, and secondary and tertiary benefits may accrue from additional jobs in manufacturing operations that use lithium products. Environmental and security benefits would accrue in California and nationwide if a significant domestic source of lithium is available.

Title:	UC Davis West Village Energy Initiative: ARRA Cost Share Funding				
Agreement Number:	PIR-10-061	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$500,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	6/30/2011	End Date:	6/30/2014	Technology Topic:	Zero Net Energy Building Design
Award Recipient:	The Regents of the University of California, Davis			End-Market:	Ratepayers

Description:

The Energy Commission provided cost share funding for a USDOE ARRA grant to design, develop and construct an advanced on-site waste to renewable energy (WTRE) facility as a critical part of UC Davis's West Village Energy Initiative (WVEI). The WVEI is creating a new, mixed-use community in Davis, with the goal of achieving Zero Net Energy (ZNE). The project is a public-private funded project, with previous PIER funding for West Village Renewable-Based Energy Secure Community project, however, the tasks of this project include the design development and construction drawings for the WTRE's biodigester and biogas facility, and for nine months of data collection and analysis to verify the performance and efficiency of the WTRE facility.

Objectives:

1. Remove barriers that prevent the commercial deployment of biogas generation in California and beyond
2. Assist in making UC Davis West Village a Zero Net Energy "ZNE" community

Benefits:

Renewable energy produced from the WTRE will enable a secure community electricity grid with increased power reliability and quality, competitive management & operations and electricity costs, and drastically reduced peak energy demand, transmission and distribution losses and greenhouse gas emissions. West Village (WV) will serve as a model approach for the implementation of community scale renewable energy deployment.

Title:	SMUD Community Renewable Energy Deployment				
Agreement Number:	PIR-11-005	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$500,000	Match Funding:	$10,136,385	Natural Gas Funding:	$0
Start Date:	6/15/2012	End Date:	12/31/2014	Technology Topic:	Other
Award Recipient:	Sacramento Municipal Utility District			End-Market:	Ratepayers

Description:

This project is demonstrating and deploying renewable energy technologies that will generate a total capacity of up to 5.2 MW from four renewable energy facilities namely: solar PV deployment project, called Simply Solar, in a closed landfill, co-digestion of fats oil and grease at the Sacrament Regional Wastewater Treatment Facility, and anaerobic digestion of dairy manure at two dairy facilities. The renewable electricity generated from these facilites are being exported to the grid bringing clean, reliable and affordable energy technologies to the marketplace.

Objectives:

1. Install up to 5.2 MW of renewable energy technologies and generate up to 37 gigawatt-hours per year of electricity
2. Reduce carbon dioxide emissions of up to 24,000 tons/year
3. Meet or exceed the California Air Resources Board's 2007 air emission standards, particularly for nitrogen oxide
4. Use excess heat by employing combined heat and power (CHP) applications
5. Lower levelized costs of electricity for solar PV and anaerobic digesters
6. Create over 200 jobs and an additional $9 million of output

Benefits:

This project successfully deployed four renewable energy facilities as described above that are now undergoing performance monitoring and demonstration. The success of the project and the lessons learned will help advance California renewable energy and greenhouse gas emission reduction goals. The project will also help accelerate the deployment and market penetration of renewable energy technologies making use of otherwise overlooked resources, including marginal, disturbed, and publicly owned lands and waste biomass resources. In the case of biomass, the environmental benefits of utilizing biogas for CHP are substantial, preventing the release of predominantly methane-containing biogas to the atmosphere and displacing the need for an equivalent amount of fossil fuel. Biogas in CHP applications further results in energy savings from utilization of waste heat.

Title:	Plumas Energy Efficiency and Renewable Management Action Plan (PEER MAP)				
Agreement Number:	PIR-12-003	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$300,000	Match Funding:	$75,000	Natural Gas Funding:	$0
Start Date:	6/19/2013	End Date:	3/31/2015	Technology Topic:	Planning
Award Recipient:	Sierra Institute for Community and Environment			End-Market:	Ratepayers

Description:

The goal of Plumas Energy Efficiency and Renewable Energy Management Action Plan (PEER MAP) is to identify, develop, and begin to implement a renewable energy plan for Plumas County that focuses primarily on forest biomass and secondarily on solar photovoltaic (PV) technology – the two most abundant sources of renewable energy in the county.

Objectives:

1. Establish PEER MAP advisory body
2. Identify and produce feasibility reports for critical facilities in Plumas County
3. Develop financial proformas for facilities
4. Develop PEER MAP Energy Vision
5. Produce various policy and barrier issues reports
6. Explore solar PV feasibility
7. Obtain partner commitments
8. Develop network of biomass boilers
9. Develop 3 MW combined heat and power facility

Benefits:

Plumas Energy Efficiency and Renewables Management Action Plan addresses the economic, environmental, and social challenges facing not only Plumas County, but many other rural forested communities in Northern California. When Fully implemented PEER MAP can save Plumas County tax payers more than $200,000 in heating costs and reduce fossil fuel consumption by more than 175,000 gallons per year. Replacing aging heating oil boilers with state of the art biomass boilers and providing an alternative to open pile burning will improve air quality across the county. Installation of solar PV panels at Feather River College, in conjunction with their current geothermal systems and proposed biomass boiler, will make FRC a model for how multiple forms of renewable energy can be integrated into college and university campuses. Greater demand for forest biomass will increase forest managers' ability to implement silvicultural prescriptions that promote forest health and resilience in the face of climate change and higher fire risk. Finally, a stronger forest products sector and new employment opportunities will have significant positive impacts on the local economy.

Title:	Energizing Our Future: Community Integrated Renewable Energy (CIRE) Assessment				
Agreement Number:	PIR-12-010	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$300,000	Match Funding:	$300,000	Natural Gas Funding:	$0
Start Date:	6/24/2013	End Date:	3/31/2015	Technology Topic:	Other
Award Recipient:	Department of the Environment- City and County of San			End-Market:	Ratepayers

Description:

This project will assess the feasibility of a community energy center, integrating district heating and cooling, renewable electricity, waste-derived biogas, geothermal heat pumps, regenerative breaking energy from public transportation, demand response, and smart distribution technology to serve multiple community members. The final product will recommend specific near-term technical actions to help achieve the State's long-term vision and analyze the local and statewide economic and environmental benefits.

Objectives:

1. Investigate and identify barriers and economics of community DG on the secondary network
2. Study enabling technologies to link community DG
3. Study energy storage and generation for community DG
4. Study district thermal energy for the central corridor in San Francisco
5. Data collection and analysis of potential economic and energy benefits

Benefits:

This project studies the benefits of carefully planned, community-scale, renewable energy systems to property developers, property owners, tenants and for the City of San Francisco. Its investigation of the feasibility of various community-scale renewable energy systems can be applied to cities throughout the state of California. The benefits of these systems include lower development costs, reduced capital and operating costs, higher property values, reduced living expenses and sustainability.

Title:	Davis Future Renewable Energy and Efficiency ("Davis FREE")				
Agreement Number:	PIR-12-011	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$300,000	Match Funding:	$75,000	Natural Gas Funding:	$0
Start Date:	6/1/2013	End Date:	3/31/2015	Technology Topic:	Solar PV
Award Recipient:	City of Davis			End-Market:	Ratepayers

Description:

The project will develop highly detailed and comprehensive integrated renewable energy and enhanced energy efficiency deployment plans that will be linked to goals and milestones in the CAAP. The project will (1) expand the City's existing GIS spatial analysis system to allow parcel-specific data development on the potential for renewable energy and enhanced efficiency measures; (2) develop analytical and modeling tools to support building owner and ratepayer decision making on energy and efficiency investments; (3) develop Zero Net Energy Retrofit Guidelines for existing residences, and a rapid deployment for solar water heating.

Objectives:

1. To develop databases, supply curves, and net zero building guidelines to determine which initiatives recommended in previous analyses should receive priority in the next phase of the Recipient's Climate Action and Adaptation Plan (CAAP) implementation
2. To develop methodologies and community energy flow models that will be used to plan subsequent community renewables deployment phases

Benefits:

The Davis FREE program is intended to develop information and deployment plans that will encourage and enable Davis residents and business to invest in renewable energy and enhanced efficiency. The results will directly contribute to the carbon reduction goals of AB 32, the California RPS, the Renewable Electricity Standard (RES), the Million Solar Roofs photovoltaic initiative, and Executive Order S-06-06 addressing biomass to electricity goals. Information developed in this project will further the state's interests in Zero Net Energy (ZNE) building design research and construction, and will contribute new cost of generation supply curves that will inform future research.

Title:	MaxSun - a novel community-scale renewable solar power system for California				
Agreement Number:	PIR-12-012	Project Number:	1	Research Stage:	Technology Development
Electricity Funding:	$525,000	Match Funding:	$155,659	Natural Gas Funding:	$0
Start Date:	6/14/2013	End Date:	3/31/2015	Technology Topic:	Solar PV
Award Recipient:	Cogenra Solar, Inc.			End-Market:	Ratepayers

Description:

This proposed project will develop a novel solar power co-generation system (MaxSun) that will generate electricity from concentrated photovoltaic solar cells (CPV) in addition to capturing and delivering the generated heat in the form of hot water to thermal loads in a combined heat and power configuration.

Objectives:

1. Develop and design a high-temperature hybrid photovoltaic/thermal solar power generation system
2. Optimize the performance of the system to operate efficiently under intended operating conditions
3. Develop software to control the system and to dynamically optimize the value of the delivered energy
4. Building, test, operate, analyze and validate a pilot-scale system that implements the novel approach.

Benefits:

The system developed under this project integrates CPV and solar thermal technologies in a hybrid system CHP configuration with demand response and thermal storage to generate as much electricity directly from sunlight as is practical through CPV, capture the remaining solar energy as heat, store the heat as hot water, and convert it on demand into electricity. Harnessing this heat mitigates the intermittency and low-efficiency of PV, dramatically reducing the cost to customers.

Title:	Predictable Solar Power and Smart Building Management for California Communities				
Agreement Number:	PIR-12-016	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$1,726,438	Match Funding:	$1,025,822	Natural Gas Funding:	$0
Start Date:	6/19/2013	End Date:	3/31/2015	Technology Topic:	Solar PV
Award Recipient:	Cool Earth Solar, Inc.			End-Market:	Ratepayers

Description:

The project aims to demonstrate and evaluate a repeatable community-scale energy model that incorporates a full value chain of generating solar energy, forecasting the availability of that solar generation, and developing proactive building energy management tools to adapt to the solar forecasts. The results and lessons learned from this project will help numerous other California communities address the efficient use of concentrating photovoltaics technologies and optimize the use of localized renewable energy resources.

Objectives:

1. Install 100kW of CPV, achieving a 75%+ performance ration and 90%+ availability factor
2. Install 12 solar met stations. Met stations will accurately read Direct Normal Irradiance (DNI) measurements to within 4% Root-Mean-Square (RMSE), and be capable of transmitting data and cloud image files to Lawrence Livermore National Laboratory (LLNL) every minute.
3. Develop, demonstrate, and verify a solar power forecast method for up to an hour ahead that relies on an inexpensive networked array of instruments and public satellite imagery. Increase the temporal and spatial resolution of cloud and aerosol tracking from 1 kilometer (current state of the art) to 1 meter (sky imagers)
4. Develop, demonstrate, and verify improvements in building energy power use and demand reduction by implementing an energy use forecast from environmental factors (solar + weather). By predicting future energy needs and solar generation, it is expected to reduce heating, ventilation, and air-conditioning (HVAC) power demands by up to 10%.
5. Document and communicate the lessons and successes form this model to relevant stakeholders including other California communities, regional governments, municipal utilities, research institutions, and business groups.

Benefits:

The benefits of this project are primarily related to cost reductions for concentrating photovoltaic (CPV) technologies. The CPV system demonstrated in this project uses a low-cost inflatable plastic tube liner fresnel optic to dramatically reduce concentrator and racking costs, as well as an innovative, minimally-invasive radial tracker to streamline deployment for a range of potential commercial, industrial, and institutional settings.

Title:	Renewable Energy Regional Exploration Project				
Agreement Number:	PIR-12-018	Project Number:	1	Research Stage:	Road Mapping
Electricity Funding:	$139,830	Match Funding:	$72,352	Natural Gas Funding:	$0
Start Date:	6/8/2013	End Date:	3/31/2015	Technology Topic:	Renewables
Award Recipient:	South Tahoe Public Utility District			End-Market:	Policymakers/ Regulators

Description:

This proposed project will provide cost share funding for a USDOE ARRA grant to design, develop and construct an advanced on-site waste to renewable energy (WTRE) facility as a critical part of UC Davis's West Village Energy Initiative (WVEI). The WVEI is creating a new, mixed-use community in Davis, with the goal of achieving Zero Net Energy (ZNE). The project is a public-private funded project, with previous PIER funding for West Village Renewable-Based Energy Secure Community project, however, the tasks of this project include the design development and construction drawings for the WTRE's biodigester and biogas facility, and for nine months of data collection and analysis to verify the performance and efficiency of the WTRE facility.

Objectives:

1. Develop a model, evaluation criteria, and processes for a community plan to integrate renewable energy
2. Coordinate with regional electric utility distribution grid operations among other independent stakeholders
3. Develop a strategic renewable energy plan for the STPUD/Liberty Utilities region

Benefits:

Benefits from this project include cost reduction and reduced environmental impacts to electricity rate payers, reliability improvement to the Liberty Utilities grid, establishment of renewable energy policies associated with the regional schools, and identification and future development of unique water system/electrical grid integrating concepts that support the Tahoe Regional Planning Agency's "environmental Redevelopment" focus. The results will directly contribute to the carbon reduction goals of AB 32, the California RPS, the Renewable Electricity Standard (RES), and Executive Order S-06-06 addressing biomass to electricity goals. Information developed in this project will be transferable to other mountain and rural communities in California.

Title:	Breakthrough Power Density for Rooftop PV Applications				
Agreement Number:	PIR-12-019	Project Number:	1	Research Stage:	Technology Development
Electricity Funding:	$475,095	Match Funding:	$325,692	Natural Gas Funding:	$0
Start Date:	6/7/2013	End Date:	3/31/2015	Technology Topic:	Solar PV
Award Recipient:	Sun Synchrony			End-Market:	Ratepayers

Description:

The goal of this project is to generate greater efficiencies in solar energy conversion than is currently feasible with flat-plate PV, resulting in more power per square meter of rooftop. The project will advance the state of the art in rooftop concentrating photovoltaics (CPV) thereby supporting enhanced penetration of the technology to buildings and institutions within the state. This project will develop a new type of rooftop-deployable PV module using light concentration to provide breakthrough power conversion efficiency. The project will integrate a CPV module with a novel tilt-up tracker and power conversion electronics to create a community-scale generation system with high power density.

Objectives:

1. Lower installed cost of rooftop CPV
2. Increase energy production with novel tilt-up tracker
3. Hit module power density by area and weight targets
4. Self-stow to flush in-base flat position triggered by high winds or drive failure
5. Scalable plan for maintaining site performance and testing

Benefits:

With this breakthrough in concentrating solar photovoltaic technology, California electricity consumers will have an option to generate more electricity in a smaller space than they can with today's most efficient flat-plate panels. If fully commercialized, this technology has the potential to contribute substantially to California's RPS, GCEJP and AB32 goals, and to fulfill a major fraction of the Governor's Clean Energy Job Goal of 12,000 MW of localized renewable generation.

Title:	Repowering Humboldt with Community Scale Renewable Energy				
Agreement Number:	PIR-12-022	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$1,750,000	Match Funding:	$1,793,762	Natural Gas Funding:	$0
Start Date:	6/19/2013	End Date:	3/31/2015	Technology Topic:	Renewables

Award Recipient:	Redwood Coast Energy Authority	End-Market:	Ratepayers

Description:

The project will demonstrate, deploy, and integrate a number of promising renewable energy technologies within Humboldt County, California. The technologies to be deployed include an innovative biomass gasification and fuel cell system to provide combined heat and power for a local facility, as well as an evaluation for optimized deployment of other distributed energy resources within the region. The lessons learned from this project are expected to benefit a variety of other communities across California seeking to develop localized renewable energy resources.

Objectives:

1. Demonstrate a cutting edge distributed biomass gasification system that produces syngas with at least a 60% hydrogen content
2. Integrate the biomass gasifier with a pressure swing absorption cleanup system and a proton exchange membrane fuel cell, and demonstrate successful operation of the first-of-its-kind integrated system. Successful operation will be a measured as a peak electrical output of >175 kW, a capacity factor of >75%, a biomass-to-electricity efficiency of >25%, and an overall system energy efficiency (including waste heat recovery) of >50%.
3. Publish at least two journal articles, present at one conference, and post information on at least three energy organization websites to publicize biomass project results
4. Implement an innovative, community-based energy upgrade model that is shown to be economically self-sustaining and secures a robust participation of at least 20-60 site assessments and 10-20 energy upgrade projects
5. Secure the participation of one or more local lenders in a local energy upgrade financing program and provide loans to 5-10 participants
6. Install air source heat pumps in two facilities and monitor performance in terms of energy, cost, and greenhouse gas emission savings.
7. Install and monitor two electric vehicle charging stations and record >100 charging events.

Benefits:

This project offers many potential benefits to California's electricity ratepayers. First, by demonstrating a distributed biomass energy system that can be scaled-up and replicated to provide 1,400 MW of renewable DG capacity in the state, especially in rural counties with substantial timber and agricultural biomass residues. This includes the typical benefits attributed to DG systems: power provided on location, higher overall efficiency, lower transmission and distribution system costs, reduced energy losses in the T&D system, and lower environmental impacts when compared to central-station generation. The proposed biomass energy system utilizes a local renewable energy resource to provide steady, reliable baseload power. If the system uses forest residue for energy production, it can also reduce fire hazards, improve forest ecosystem health, and increase timber production. Economically speaking, biomass energy is estimated to create more local jobs than other renewable energy resources.

The energy upgrade program offers additional ratepayer benefits. These include cost savings through increased energy efficiency to homes and businesses and a decrease in energy consumption and carbon emissions. The program demonstrates a streamlined customer/contractor model that offers lower costs and increased security to both parties. Local lenders will be engaged to provide simplified and easily accessible financing. The program is expected to be easily replicable throughout the state.

Title:	Camp Pendleton Area 52 FractalGrid Demonstration Project				
Agreement Number:	PIR-12-033	Project Number:	1	Research Stage:	Technology Demonstration
Electricity Funding:	$1,722,890	Match Funding:	$1,172,428	Natural Gas Funding:	$0
Start Date:	6/30/2013	End Date:	3/31/2015	Technology Topic:	Microgrids
Award Recipient:	Harper Construction Company, Inc.			End-Market:	Energy Suppliers

Description:

This project will demonstrate a set of intelligent microgrids that use community-scale renewable energy resources and energy storage within an existing utility grid at Camp Pendleton, which is a large marine base with dispersed loads and generation. The energy generation and demand will be optimized by installation of the power controllers, distribution and isolation switches and local energy storage, and analysis of critical mission priorities. This project will identify project constraints and priorities to reduce energy and peak demand by 10% while meeting base priorities.

Objectives:

1. Reduce kilowatt hours per day by 10% during the demonstration period by optimizing generation and load resources
2. Reduce Peak Demand kilowatts by 10% during the demonstration period by using energy storage to optimize generation and load resources
3. Reduce the carbon footprint by at least 5% against the baseline by using solar forecasting
4. Demonstrate the grid-independent ability of multiple distributed microgrids (from the local utility grid as well as from other microgrids) with FractalGrid architecture

Benefits:

This project will develop an enhanced, renewable microgrid that meets the demands of community energy security as well as high-risk clients such as large industrial institutions and army bases. The system will combine renewable energy resources with traditional generation assets and energy storage to shed loads based on criticality to support community functions and provide long-term energy security.

Title:	Methodology to Develop Energy Baselines for California's Regions				
Agreement Number:	500-10-033	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$1,000,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	4/11/2011	End Date:	10/31/2014	Technology Topic:	Benchmarking
Award Recipient:	The Regents of the University of California on behalf of the			End-Market:	Ratepayers

Description:

This project will develop new methodologies and integrated tools to analyze and establish baselines of energy and materials flows for California's metropolitan region. Outcomes from developed methods for collecting socio-economic, demographic, and land use data that can be combined with regional energy baseline data to assess community energy consumption will enable stakeholders to better target reduction policies and mitigate impacts based on how, where and why energy is being used. This project uses and builds upon the statewide Production, Exchange, and Consumption Allocation System (PECAS) model to inform and promote sustainable community policies and to improve existing tools.

Objectives:

1. Develop a set of methodologies for the development of energy baselines from which regional sustainability assessment can be conducted.
2. Develop a set of methods and indicators for evaluating the relationship between. socio-economic factors and energy use in California communities.
3. Pilot the methodologies and indicators described above in Los Angeles County.

Benefits:

This project will develop and help bring to market advanced transportation technologies that reduce air pollution and greenhouse gas emissions, beyond applicable standards, offering environmental and health benefits. The project also supports California's goal to establish a strategic planning process with local governments and regional planning organizations to reduce transportation fuel consumption through improved public transportation and land use planning offering cost benefits.

Title:	California Center for Sustainable Communities at UCLA				
Agreement Number:	500-11-012	Project Number:	1	Research Stage:	Policy/Regulation Support
Electricity Funding:	$1,900,000	Match Funding:	$0	Natural Gas Funding:	$0
Start Date:	4/4/2012	End Date:	6/30/2015	Technology Topic:	EV Charging Stations
Award Recipient:	The Regents of the University of California on behalf of the			End-Market:	Ratepayers

Description:

The purpose of the project is to develop a California Center for Sustainable Communities (CCSC) that will synthesize, coordinate, and communicate sustainable energy systems research and development to 1) reduce energy use through improved community design and integrated land use and transportation practices; and 2) increase faster adoption of lower emission electric vehicles by providing tools that will help municipalities provide public infrastructure to benefit electricity ratepayers.

Objectives:

1. Reduced energy use through improved community design and integrated land use and transportation practices.
2. Reduced vehicle miles traveled and GHG emissions through more sustainable land use and transportation planning.
3. Reduced legal and policy barriers to resource-efficient communities and streets.
4. Increased prevalence of pedestrian friendly street environments through use of rating system for pedestrian environments and thermal comfort modeling.
5. Faster adoption of lower emission electric vehicles by providing tools that will help municipalities provide public infrastructure.

Benefits:

Electricity ratepayers benefit from reduced GHG emissions and increased energy savings through the support of local governments and regional MPOs that create resource efficient communities by that encourage alternative forms of transportation, reduce the use of automobiles and trucks, and increase the overall energy sustainability of cities by better land use planning and system design. Examples of support for local government include providing timely, valuable and unbiased information via the CCSC website on impacts of land use on California's energy challenge and creating a tool that makes research accessible across three related areas: (1) the demand for EV; (2) the usage patterns of EV; and (3) the charging infrastructure necessary to serve EV. The website and tools are open access so ratepayers (consumers) benefit from the available knowledge.

Title:	The Market Impact of Standardized Design in PEV Battery Pack Purchase and Disposal				
Agreement Number:	PIR-12-005	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$750,000	Match Funding:	$150,000	Natural Gas Funding:	$0
Start Date:	6/19/2013	End Date:	3/31/2015	Technology Topic:	Battery
Award Recipient:	Electricore, Inc.			End-Market:	Ratepayers

Description:

Electricore, in collaboration with the California Center for Sustainable Energy (CCSE), SDG&E, and Ricardo, completed an in-depth study on how standard system designs for plug-in electric vehicle battery packs can potentially meet requirements for original equipment manufacturers, vehicle customers, remanufacturers, and second use applications as well as quantified the economic impact of such standardization. They have developed potential design options for the standardization of battery modules for vehicle and second use applications and have identified barriers as well as provided recommendations for implementing standardized battery system design.

Objectives:

1. Evaluate how standard system designs compare to the current non-standard systems in their ability to meet original equipment manufacturer, vehicle customer, remanufacturer, and second use system requirements; including performance, form factor, manufacturability, cost, and longevity.
2. Quantify the impact on battery system costs of standardization for each stakeholder in the battery pack value chain.
3. Identify the barriers to a standard battery system design.
4. Quantify the added value for a standard system compared to a non-standard system when sold to secondary application markets.
5. Identify and evaluate potential pathways for implementation of PEV battery pack standards.

Benefits:

Electricore surveyed stakeholders in the battery pack value chain (original equipment manufacturers, vehicle customers, remanufacturers, customers for second use applications) to determine the necessary requirements and needs, and used the results to develop two standard battery pack designs for commercial vehicles. A cost-benefit analysis was completed based on a value chain assessment of the battery system life cycle, and determined that standardization has the potential to reduce the delivered battery price to vehicle manufacturers by 3 to 15 percent. Additionally they provided recommendations for potential pathways to battery pack standardization.

Title:	Direct Recycling Technology for California's PEV Li-ion Battery Packs				
Agreement Number:	PIR-12-006	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$749,710	Match Funding:	$149,943	Natural Gas Funding:	$0
Start Date:	6/19/2013	End Date:	3/31/2015	Technology Topic:	Battery
Award Recipient:	Farasis Energy, Inc.			End-Market:	Ratepayers

Description:

Farasis Energy, Inc. is developing and demonstrating the technical and cost feasibility of a novel recycling technology known as Direct Recycling, designed specifically for large lithium-ion battery packs such as those used in plug-in electric vehicles. Direct Recycling allows for the full recovery of the high value electrode active materials and conductive additives, including but not limited to lithium and graphite, which accounts for more than 60 percent of the battery material cost. The recovered materials are separated, purified to remove contaminants, and regenerated to be used in the production of new lithium-ion batteries. The research team will take used lithium-ion batteries, harvest and process the high-value recyclable materials through the Direct Recycling process, and manufacture pouch cells using the recycled materials for testing and analysis. Data collected from the demonstration will be used to develop an accurate cost model for implementing the technology throughout California.

Objectives:

1. Develop processes and characterize materials to demonstrate that the Direct Recycling approach can produce lithium ion battery active materials similar in performance to newly synthesized battery materials that are suitable for reuse in performance to newly synthesized battery materials that are suitable for reuse in new lithium ion batteries for electric vehicle applications.
2. Optimize and demonstrate that the recycling process steps have the potential to recover and regenerate active and inactive materials with high yield.
3. Demonstrate that the approach is suitable for the dominant lithium ion battery waste streams expected for plug-in electric vehicle systems in California.
4. Demonstrate one life cycle of a lithium ion cell at lab scale through aging plug-in electric vehicle suitable lithium ion cells, using the Direct Recycling processes developed to recover and regenerate the active materials, and using them to make new lithium ion cells.
5. Develop a cost model for recycling large lithium ion battery systems using the Direct Recycling approach by analyzing the cost of scaling the process step, throughput, and yields for all inactive and active components to be recycled.

Benefits:

Successful development and demonstration of the Direct Recycling process will accelerate the growth of low cost, self-supporting recycling infrastructure for used lithium-ion battery packs. This advanced recycling process will help create a sustainable market for energy efficient applications of recyclable lithium-ion energy storage systems and would consequently lead to new material supply streams for lithium-ion battery manufacturers, reducing the battery cell costs by an estimated 20 to 40 percent and ultimately reducing plug-in electric vehicle battery costs for consumers. Lastly, as the electric vehicle market continues to grow, successful demonstration of Direct Recycling will keep hazardous materials found in used electric vehicle batteries out of California’s landfills.

Title:	Strategies for Sustainable and Cost-Effective Scale-up of Second-Life, Recycling, and Disposal Pathways for PEV Battery Packs				
Agreement Number:	PIR-12-015	Project Number:	1	Research Stage:	Applied Research
Electricity Funding:	$250,290	Match Funding:	$51,000	Natural Gas Funding:	$0
Start Date:	6/19/2013	End Date:	3/31/2015	Technology Topic:	Electric Vehicles
Award Recipient:	Lawrence Berkeley National Laboratory			End-Market:	Ratepayers

Description:

Under this agreement, Lawrence Berkeley National Lab is developing strategies for the scale-up of plug-in electric vehicle battery recycling infrastructure in California. Based on the recycling scenarios, the team is also creating and applying a cost and environmental impact model that calculates transportation distances and determines optimal battery collection and recycling facility locations.

Objectives:

1. Develop scenarios to estimate potential consumer adoption of PEVs in California and the resulting battery disposal rates
2. Establish a set of cost and environmental metrics by which to compare battery recycling and reuse strategies.
3. Create optimal large-scale recycling infrastructure and logistics scenarios and estimate the environmental implications for each.
4. Make results from the environmental assessment and infrastructure scenarios available to guide future recycling process development in prioritizing particular materials, or taking steps to reduce transportation and capital costs, such as the ability to recycle multiple battery types in a single facility.

Benefits:

The scenarios created under this agreement will inform industry on the rate in which plug-in electric vehicle battery recycling infrastructure must be scaled up in California as well as the identification of optimal facility functions, locations, and transportation logistics. This strategic development will minimize capital costs, transportation distances, and environmental impacts associated with plug-in electric vehicle battery recycling.

APPENDIX B:
Benefits Methodology

Energy Efficiency Calculations

Estimates for Energy Savings

The estimates for energy savings resulting from efficiency-related projects presented in Tables 2, 3, 4, and 5 of Chapter 3 were calculated as follows:

1. The Energy Commission collected data on benefits measured or expected from PIER funded projects that were active in 2014 and estimated future technology transfer efforts. Data sources included final project reports, project proposals, direct communication with award recipients, or third-party sources. The data were limited to electricity savings, natural gas savings, and peak electrical load reduction. Where available or necessary, the data were provided as ranges. Ranges were necessary in some cases for projections to 2020, as market conditions remain to be seen. Many projects were omitted from this process because the stage of research was too early to provide sound data needed for an estimate of benefits.

2. The Energy Commission combined the data provided with the latest Commission demand forecast for the relevant energy end-use sector (for example, residential, commercial, and industrial).[77] In the case of projects related to data centers, a separate projection of electricity demand in 2020 was developed in expectation that data center electricity demand would grow substantially faster than the commercial or industrial sectors. The resulting forecast growth was based on projections prepared for the U.S. Energy Information Administration.[78]

3. Where estimates of future market uptake were not available, the potential benefits were evaluated at a conservative one percent realization of technical potential. Technical potential is defined as the benefits that would occur in California if the entire sector, ratepayer class, or other relevant market grouping adopted the technology. A factor of 1 percent is applied to the technical potential to provide conservative estimate of the benefits from actual market uptake. In a few cases, however, provided data justified the forecast of a greater level of market penetration. These are noted in the table of potential savings.

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77 Alcorn, Bryan et al. 2013. *California Energy Demand 2014–2024 Final Forecast.* California Energy Commission, Electricity Supply Analysis Division. CEC-200-2013-004. http://www.energy.ca.gov/2013publications/CEC-200-2013-004/CEC-200-2013-004-SD-V1.pdf.

78 Navigant Consulting and SAIC. 2013. *Analysis and Representation of Miscellaneous Electric Loads in NEMS.* Prepared for U.S. EIA. http://www.eia.gov/analysis/studies/demand/miscelectric/pdf/miscelectric.pdf .

4. Emissions factors for electricity and natural gas were applied to the estimates of energy savings. The sources and assumptions for these emissions factors are discussed below.

5. Monetary savings were estimated as the product of forecast average energy rates in 2020 and energy savings, per the rate forecasts in the 2014-2024 Commission demand forecast. Additionally, the value of GHG emission reductions was calculated at $11.5 per metric ton (November 2013 market clearing price), and $118 per kW of peak load reduction (as an estimate of the capacity value of peaker generation).

6. For most projects, only point estimates of benefits were available. For other projects, ranges of possible values were provided. To provide estimates of central tendency as well as a range of high and low values for entire set of evaluated projects, staff applied statistical theory. The procedures are as follows:

    - Point estimates were turned into bell-shaped normal probability distributions, centered at the estimate. For demonstration projects, 95 percent of the probability mass was within 10 percent of the estimate, meaning the estimate as interpreted as being within 10 percent of the correct value, with 95 percent confidence. For projections to 2020, the variance was widened by setting a standard deviation of a third of the value. This treats the estimate as having more than two thirds probability of being within one third of what the market will ultimately determine.

    - Ranges were turned into uniform distributions, meaning the same likelihood was assigned to any number in the range.

    - Sometimes lower bounds were given without upper bounds (for example, "energy savings are at least x"). These were turned into the right half of a normal distribution peaking at the lower bound and tapering to higher numbers with a standard deviation of one-third of the lower bound.

    - Where low, high, and medium estimates were provided, the most weight was put on the medium estimate. This was accomplished by creating a skewed normal curve, with its peak at the medium estimate and 95 percent of the values between the lower and higher estimates.

    - The method used for combining probability distributions was repeated random simulations. In each simulation, a draw from each project's probability distribution was made, and the different projects were added together. Collectively, the simulations specified a distribution for the final outcome, total carbon or dollar savings. This approach is common in statistics.

    - Once each project's estimate of carbon or dollar savings was converted into a probability distribution, the distributions were combined to create a final distribution. The mean of that distribution was reported as the total, and for potential savings the 25th and 75th

percentiles were reported as the low and high values in parentheses. These can be considered low and savings high scenarios.

7. The results refer only to benefits. Cost data were not available. The evaluated projects were anticipated to deliver benefits greater than costs to ratepayers because of their substantial technical successes. However, realized costs will depend on a variety of factors that occur during commercialization, such as economies of scale achieved the financing costs faced by the firm delivering the new technology to ratepayers. Further, the benefits evaluated are limited only to electricity savings, natural gas savings, and peak demand reduction. Benefits such as water savings or the avoidance of waste disposal were not evaluated.

In-Depth Analysis Calculations

Environmental Impact of Avoided Electric Generation

The climate forcing and criteria pollutant emissions estimated in this report follow the methodology provided in the following source:

Alvarado, Al and Joe Loyer. 2012. *Criteria Air Emissions and Water Use Factors for Gas and Electricity Efficiency Savings for the 2013 California Building Energy Efficiency Standards.* California Energy Commission.[79]

The assumptions of this paper are updated here with the latest values to refine the analysis. These are noted in the discussion below.

The electric generation displaced by ratepayer energy savings is assumed to consist of a mix of natural gas and Renewables Portfolio Standard (RPS) eligible resources. For the year 2020 and beyond, the RPS requirements correspond to 33 percent of retail sales. For years prior, this percentage follows the compliance schedule provided on the CPUC's website.[80]

Additionally, avoided generation is assumed to consist of a mix of in-state and out-of-state resources. Per Alvarado and Loyer (2012), the marginal fraction of in-state fossil generation is set at 75 percent. Per the *Energy Aware Planning Guide*, the marginal fraction of in-state RPS generation is set at 80 percent.[81]

Ratepayer electricity savings must be "grossed-up" to account for transmission and distribution losses (T&D losses), which necessitate that more electricity be generated at power plants than is ultimately consumed by ratepayers. Alvarado and Loyer provide the following loss rates:

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79 http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/current/Reports/General/2013_Initial_Study_Air_and_Water_Emission_Factors.pdf.

80 http://www.cpuc.ca.gov/PUC/energy/Renewables/hot/33RPSProcurementRules.htm.

81 California Energy Commission. 2011. *Energy Aware Planning Guide*. Commission Report. CEC– 600–2009–013. Section II: Overview, Page 5.

- In-State Generation: 7.8 percent
- Out-of-State Generation: 9.8 percent

Loss rates are used to calculate avoided net energy for load (total generation by power plants to serve retail electricity sales) as follows:

$$Avoided\ Net\ Energy\ for\ Load = \ Avoided\ Retail\ Sales\ x(1 - Loss\ Rate) - 1$$

To estimate avoided GHG emissions, both in-state and out-of-state generation sources are considered. Non-CO_2 gases are ignored as they constitute a trivial fraction of the total global warming fraction of post-combustion natural gas.[82] A lifecycle analysis was not undertaken. The CO_2 emission rate for the marginal natural gas power plant is taken as 382 kg per megawatt (MWh), which is estimated as the product of the average heat rate of combined-cycle natural gas plants in California in 2012 (7,228 btu/kWh)[83] and the carbon intensity of natural gas combustion per unit input (53.02 kg CO_2/mmBtu).[84] To enable sensitivity analysis, emissions factors associated with the range of heat rate rates provided in Alvarado and Loyer (2012) (7,000btu/kWh to 8,000 Btu/kWh) were retained.

For the GHG emissions of RPS resources, this analysis follows the assumption of the *Energy Aware Planning Guide* that one-third of new RPS resources will be geothermal, which is associated with small but measureable GHG emissions during operation (7.5 kg per MWh).[85] Emission factors are calculated for in-state natural gas, in-state RPS, out-of-state natural gas, and out-of-state RPS. Then, they are weighted by their relative share in the marginal power mix. For the year 2013, the result is 334.9 kg per MWh. For the year 2020, the result is 281.8 kg per MWh.

Reductions in ratepayer natural gas consumption are estimated to reduce GHG emissions in all years by a factor of 5.302 kg CO_2 per therm.[86]

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82 U.S. EPA. Emission Factors for Greenhouse Gas Inventories. http://www.epa.gov/climateleadership/documents/emission-factors.pdf.

83 Internal California Energy Commission data.

84 California Energy Commission. 2011. *Energy Aware Planning Guide*. Commission Report. CEC– 600–2009–013. Section II: Overview, Page 5.

85 Ibid.

86 California Air Resources Board. 2013. *Unofficial electronic version of the Regulation for the Mandatory Reporting of Greenhouse Gas Emissions*. Page 115. http://www.arb.ca.gov/cc/reporting/ghg-rep/regulation/mrr-2013-clean.pdf .