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ENERGY COMMISSION

Edmund G. Brown Jr., Governor

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ENERGY COMMISSION

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ABSTRACT

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

In Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006), the Legislature declared 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 make research investments in the following four categories:

- Increased energy efficiency in buildings, appliances, lighting, and other applications beyond applicable standards
- Advanced electricity technologies that reduce or eliminate consumption of water or other finite resources, increase use of renewable energy resources, or improve transmission or distribution of electricity generated from renewable energy resources
- Advanced electricity generation technologies that exceed applicable standards to increase reductions in greenhouse gas emissions from electricity generation
- Advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards

The Energy Commission's *PIER 2011 Annual Report* is prepared under Public Resources Code Section 25620.8. This report describes PIER electric funding and accomplishments in 2011, including activities and research projects funded from January 1, 2011, through December 31, 2011, 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, Governor Brown's Clean Energy Jobs Plan, greenhouse gas, Public Interest Energy Research Program, Renewables Portfolio Standard, zero net energy, building efficiency standards, California Public Utilities Commission, combined heat and power

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TABLE OF CONTENTS

Acknowledgements ..... **i**

ABSTRACT ..... **iii**

TABLE OF CONTENTS ..... **v**

TABLE OF FIGURES ..... **viii**

EXECUTIVE SUMMARY **1**

Highlights of 2011 Research 1

Program Status 2

Key Guiding Principles for a Public Interest RD&D Program 3

Future Program Directions 4

CHAPTER 1: Introduction and Overview **5**

Report Structure 6

Policy, Planning, and Program Overview 6

PIER Research Meets Policy Objectives 7

Coordinated Efforts – Natural Gas and Electricity Research Synergies in California 8

Program Funding Overview 9

Attracting Match Funding to California 9

Creating Jobs in California 10

Program Updates and Enhancements 11

Ensuring Stakeholder Participation Through the Advisory Board and Program Advisory Groups 12

Communicating Public RD&D Benefits 13

Enhancing Public Outreach: Publications and Research Forums 14

Contract and Solicitation Reforms 15

Ensuring Direct Funding to California and Revising Solicitations 15

Intellectual Property Rights Review 16

CHAPTER 2: PIER's 2011 Research Delivers Ratepayer Benefits **17**

Energy Efficiency Research 17

Buildings End-Use Efficiency Research 17

New and Improved Products for California Consumers 18

Developing Plug-Load Solutions in California 18
Lighting Demonstrations Cut Electricity Costs 20
Saving Energy With Personal Interior Temperature Controls 21
Energy-Efficient Designs, Materials, Building Techniques, and Tools 22
Best Practices for Home Energy Retrofits in California 22
Modeling Software Helps Designers Plan for Residential Energy Efficiency 23
Improved Performance and Efficiency Standards for Buildings and Equipment 25
Reducing Energy Use in Commercial Rooftop HVAC Units 25
Improving Efficiency in New California Homes 25
Industrial, Agriculture, and Water End-Use Efficiency Research 26
Reducing Air-Conditioning Energy Use and Cost in Data Center Operations 27
Volume Server Research Yields Substantial Power Reduction for Data Centers 28
Renewable Energy Research 29
Comprehensive Concentrating Photovoltaic Makes Solar Energy More Cost-Effective 30
Renewable Energy Technology to Provide Energy Security and Prosperity in Humboldt County 31
Wind Turbines and Battery Storage Added to the Smart Grid Demonstration of Renewable Energy Secure Community at the Santa Rita Jail 31
Non-Contact Drilling Research Improves Geothermal Drilling Technology 32
Using Battery Storage to Firm/Stabilize Wind-Generated Energy 34
Energy Innovations Small Grant Program 34
Airborne Wind Turbines Reduce Average Cost of Offshore Wind Energy 35
Energy Harvesting From Ocean Currents 35
Advanced Generation Research 36
Developing Combined Heat and Power Technology to Meet Air Quality Standards 36
New, Efficient, Low-Emission Technology for Commercial Firetube Boilers 37
Energy-Related Environmental Research Enables Renewables 39
Facilitating Renewable Energy Siting in the California Desert 39
A Framework for Analyzing Cumulative Biological Impacts for Solar Energy Projects in the California Desert 39

Decision Support System to Improve Mitigation and Facilitate Siting Renewable Energy 40

Optimized Data to Enhance Renewable Energy Planning in California Deserts 41

Energy Infrastructure Research 42

Reliability Through Technology: Synchrophasors 42

Turning a California University Campus Into a Premier Microgrid Technology Demonstration Platform 43

The Future of Energy Storage in California 45

Renewable Energy and Stabilizing the Electric Grid 46

Expanding the Delivery of Renewable Energy With Intelligent Software Agent Technology 47

Reducing the Effects of Wind on Dry-Cooled Power Plant Efficiency 48

Estimating Risk to California Energy Infrastructure From Projected Climate Change 49

Climate Change Effects on California's Hydropower Resources 50

Carbon Capture and Storage at King Island, California 51

Energy-Related Transportation Research 52

Reusing Lithium-Ion Vehicle Batteries to Cut Costs and Support the Grid 52

Addressing Barriers to Plug-In Electric Vehicles in California 53

CHAPTER 3: Conclusion and Next Steps 55

Conclusion 55

Next Steps 55

APPENDIX A: 2011 Individual Electricity Research Projects 57

Acronyms 67

LIST OF FIGURES

Figure 1: PIER Electric and Natural Gas Research Budget Allocations 1997–2011 9

Figure 2: Percentages of 2011 Total Electric Funding – Research and Match..... 10

Figure 3: Counties with Active PIER Electricity and Natural Gas Research in 2011 (Shown in Green) 10

Figure 6: Example of Typical External Power Supply Use 18

Figure 4: Bilevel fixtures with Occupancy Sensors Installed in City of Sacramento Parking Garages. 20

Figure 5: Personal Environment Equipment 22

Figure 7: Example of Home Energy-Efficient Design Software Output 24

Figure 8: Rooftop HVAC Unit 25

Figure 9: Assessing Energy Efficiency in Newly Built Homes 26

Figure 10: Left: Data Center Thermal Map Before Vigilent's Active Controls Went Live; Right: Data Center Thermal Map After Vigilent's Active Controls Went Live, Reducing Overcooling While Protecting IT Equipment 28

Figure 11: The SeaMicro Device 29

Figure 12: GreenVolts' Concentrating Photovoltaic System Installed in Fremont, California 30

Figure 13: Air Photo of Santa Rita Jail Energy Complex, December 2011 32

Figure 14: Energy Storage in Modesto, California 34

Figure 15: Passively Stable Shroud for Airborne Wind Turbine 35

Figure 16: Engine Field Test of Ultra-Low Emissions System at Fontana Wood Preserving..... 37

Figure 17: Firetube BBEST System Illustration 38

Figure 18: Renewable Energy Action Team DRECP Starting Point Map Showing Renewable Energy Study Areas and Conservation Opportunity Areas 39

Figure 19: The Desert Tortoise is a State and Federally Listed Species in Need of Targeted Conservation Efforts 40

Figure 20: Mojave Desert Wildflowers in California's Mojave National Preserve 41

Figure 21: Microgrid Technology Demonstration System Complex, UC San Diego 44

Figure 22: Lithium-Ion Hybrid Ancillary Power Unit by A123 Systems 45

Figure 23: Automated Demand Response 46

Figure 24: Air-Cooled Condenser 48

Figure 25: Percent Change of Probability That a Wildfire Could Affect a Transmission Line Using Two Global Emission Scenarios. Areas in Yellow to Red Reflect the Greatest Changes. .. 50

Figure 26: New Melones Dam 50

Figure 27: Drilling Rig Running Wireline Logs 51

Figure 28: Well Trajectory Through Target Storage Formations 51

Figure 29: Second-Life Applications for Lithium-Ion Vehicle Battery Packs 53

EXECUTIVE SUMMARY

The California Energy Commission's Public Interest Energy Research (PIER) Program funds research, development, and demonstration projects (RD&D) 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."[1] Research priorities are guided by the "loading order" of preferred energy resources and legislative mandates, such as the Renewables Portfolio Standard and the Global Warming Solutions Act of 2006 (Assembly Bill 32), the Energy Commission's *Integrated Policy Reports (IEPRs),* and the PIER Advisory Board.

This Annual Report to the California Legislature, as required by Public Resources Code Section 25620.8, provides a status update on PIER, including specific information on award recipients, the amount of the awards, the types of projects funded, an evaluation of the success of projects funded and instituted, and recommendations for program improvements.

To date, the Energy Commission has invested more than $820.59 million for energy RD&D, leveraging its investment to attract more than $1.13 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 progress the state toward meeting its goals by helping remove barriers to a clean energy future.

Highlights of 2011 Research

This report illustrates projects that were completed and/or reached a significant milestone in 2011. A few examples are included here to highlight research accomplishments and ratepayer benefits.

Technology advancements in energy-efficient lighting, consumer electronics, and heating, ventilation, and air conditioning are being adopted in the state's Building and Appliance Efficiency Standards and amounting to significant energy and dollar savings for ratepayers. For example, seven efficiency measures alone are estimated to save upwards of $1 billion a year once the measures are installed and used. In 2011, three plug-load projects were initiated to help maximize energy efficiency when devices are not in use and contribute to those dollar savings.

Advancements in renewable energy technologies include the development and installation of low-cost, ground-based and rooftop solar photovoltaic technologies and tracking systems. For example, the Fremont, California-based company Green Volts' concentrated photovoltaic system demonstrated a low-cost, complete packaged renewable energy solution. To date, the technology has been deployed at several sites, with capacity ranging from 200 kilowatts to 1 megawatt. In 2011, the project attracted a private investment of $20 million, allowing business expansion in California. Community-scale renewable energy pilot programs to enable local communities to develop and exploit local renewable resources, in combination with energy

[1] Public Resources Code section 25620.1.

efficiency and demand response, and energy storage are being demonstrated across the state, from San Diego to Humboldt County. Demonstrations of wind turbines and battery storage technologies, such as those at the Santa Rita Jail in Dublin, California, are underway that will also enable local communities to safely integrate their own self-generated resources with the utility power grid. PIER projects are also demonstrating how agricultural waste can be used to produce biogas to generate electricity and satisfy a high percentage of an agricultural operation's on-site demand, reducing their cost of operation.

To prevent electricity outages and enable reliable integration of renewable energy generation, PIER funded development of a synchrophasor technology that monitors the transmission grid operations so that grid operators can take corrective actions before blackouts or grid failure occurs. In 2011, a comprehensive assessment of the benefits of 15 years of synchrophasor research determined that use of this technology by the California Independent System Operator is estimated to save Californians $210 million in reliability costs and $90 million in economic benefits annually. To help bridge a more seamless integration of the renewable energy into the grid, PIER is also investing in energy storage, intelligent software, and emerging distributed resources development and demonstrations. For example, a PIER-funded market study of storage costs was released in 2011, providing insight into the value of replacing some energy storage with automated demand response.

Researchers are conducting field testing on how to reduce water and energy needed for air-cooled condensers used in power generation plants. This research has promise to reduce power water consumption by 95 percent while increasing performance efficiencies, making dry-cooling a much more affordable alternative to traditional wet-cooling technology. In addition, tools to reduce the environmental impact of renewable energy and aid in facility siting are being developed. For example, preliminary output from two environmental modeling tools were used in 2011 for desert tortoise impact mitigation and California renewable energy planning efforts in the desert.

PIER is addressing barriers to large-scale deployment of plug-in electric vehicles (PEVs) in California. As more consumers purchase PEVs, additional electricity generation will be needed to meet the recharging demands PEV consumers. In 2011, PIER funded research determined that the air pollution and greenhouse gas benefits of PEVs will significantly offset the emissions from the added electricity generation needed for vehicle charging. Also in 2011, PIER concluded the first-ever study to evaluate the technical and economic feasibility of reusing PEV lithium-ion batteries in stationary energy storage devices. This project found that reusing PEV lithium-ion batteries for electricity storage applications could reduce battery lease payments to PEV consumers by up to 32 percent.

Program Status

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 for funding it, the Public Goods Charge (PGC). Recognizing the importance and benefits of the program, Governor Jerry Brown requested the California Public Utilities Commission (CPUC) take action to ensure that programs like those supported by the PGC are reinstituted and to take into account the

constructive ideas for program reform that were identified during the legislative process. In October 2011, the CPUC began an Order Instituting Rulemaking (OIR) process (CPUC Proceeding R.11-10-003) to determine the effect on public benefits associated with the expiration of the PGC, which also funds the state's efficiency and renewable incentive programs.

On December 15, 2011, the CPUC, in its Phase One decision, approved interim funding for public interest RD&D, which took effect on January 1, 2012, when the surcharge that funded the existing PIER Electricity Research Program ended. The Phase One Decision maintained a similar funding level from electricity ratepayers by establishing the Electric Program Investment Charge (EPIC) to fund renewable energy and RD&D programs.

The Phase One decision requires current funding levels, which average about $71 million per year for electricity RD&D, to continue on an interim basis until programmatic and governance issues can be more fully addressed in Phase Two of the proceeding.

Key Guiding Principles for a Public Interest RD&D Program

Any public interest RD&D program that succeeds PIER should continue to be guided by certain key principles to govern the program design and scope. First, any successor program approved by the CPUC would be expected to be consistent with Public Utilities Code Section 740.1, which specifies what criteria the CPUC should consider in evaluating the RD&D programs proposed by electric and gas utilities:

- Projects should offer a reasonable probability of providing benefits to ratepayers.
- Expenditures on projects that have a low probability for success should be minimized.
- Projects should be consistent with the corporation's resource plan.
- Projects should not unnecessarily duplicate research undertaken by other electrical or gas corporations or other research organizations.

Furthermore, Section 740.1 specifies that RD&D projects funded by electricity or natural gas ratepayers should support the following objectives:

- Achieve environmental improvement
- Enhance public and employee safety
- Encourage conservation by efficient resource use or by reducing or shifting system load
- Develop new energy resources and processes, particularly renewable energy resources
- Improve the operating efficiency and reliability or otherwise reduce operating costs

Under the Energy Commission, public interest has been and remains the paramount guiding theme in administering of RD&D using ratepayer funds to provide benefits to California's

citizens. Arguments have been made, and history shows, that moving the administration to a nonpublic entity would narrow the focus to private, market-driven profits. Publicly administered RD&D ensures transparent and accountable data and research results, a balanced portfolio, maximum leveraging of funds with private and other government entities, and direct accountability to the public, fund ratepayers, and the Legislature. Any future administrator of the EPIC funds should be held to these same goals and standards and should outline its funding priorities in a strategic investment plan that has been fully vetted through an open and transparent stakeholder process. It will also be incumbent on the administrator to coordinate the research portfolio with the CPUC, California Air Resources Board, utilities, and others to avoid duplication.

Future Program Directions

In 2012, the Energy Commission's RD&D program will continue to encumber fiscal year 2011/2012 funds to address critical state energy policy goals and objectives, as established by the Governor and the Legislature and guided by the PIER Advisory Board, to support research initiatives in the following areas:

- Develop and demonstrate energy efficiency technologies and inform future building and appliance efficiency standards.
- Demonstrate zero net energy buildings and energy smart communities.
- Increase energy efficiency in major energy end-use sectors, including buildings, industrial, agricultural, and water sectors.
- Advance and demonstrate demand response and energy storage technologies and incorporate these technologies into a statewide smart grid infrastructure.
- Develop renewable technologies and community and utility-scale renewable generation, and accelerate integration of renewable energy into the state's electricity grid.
- Support environmental and transportation energy research directly tied to energy generation, transmission, and use.

In 2011, the program made multiple reforms to ensure increased funding to California-based business entities and ratepayer-based locations, lower contractor overhead costs, greater leveraged funding, and increased reporting of ratepayer benefits. In 2011, the program also greatly expanded public outreach, holding more than 18 symposiums, webinars, and workshops. These events enhanced opportunities for stakeholders to both shape research initiatives in a public forum and to hear interim or final research project results. In 2012, the Energy Commission will continue public outreach and process improvements to build upon these changes. The Energy Commission is committed to achieving the benefits of a coordinated, statewide research program that avoids overlap and duplication, minimizes program costs, and shares research results to maximize openness, transparency, and accountability.

CHAPTER 1:
Introduction and Overview

The California Energy Commission's Public Interest Energy Research (PIER) Program invests in energy research, development, and demonstration (RD&D) in the areas of energy efficiency and demand response, renewable energy resources, advanced electricity generation, transmission and distribution, energy-related transportation, and energy-related environmental research. Public investment in clean energy technology plays a significant role in advancing the development and ultimate deployment of next generation technologies and tools needed to meet the state's energy goals. Federal and private support for energy RD&D is underfunded nationwide – government funds spent on RD&D have declined sharply, in inflation-adjusted terms, since the 1970s.[2] California has a long history of supporting energy technologies and strategies, and the PIER Program is one of only two state-funded premier energy RD&D programs in the United States, which has given California a competitive advantage over other states in attracting venture capital funding for energy RD&D projects and, by extension, contributes to economic growth.[3]

The Energy Commission's RD&D program plays a significant role in facilitating the development of next generation technologies needed to meet the state's energy goals.

As the ninth largest economy in the world, California has the unique ability and responsibility to fund innovative energy RD&D. Leaving RD&D decisions solely to the free market has been shown to decrease overall investments in favor of short-term profitability.

By supporting RD&D work dedicated to benefitting ratepayers and society at large, the Energy Commission manages research that removes barriers to achieving reliable, safe, and affordable energy and more electricity from renewable resources. The Energy Commission conducts public interest energy research by considering the needs of the state and its energy policies, establishing research goals for the greatest public benefit, and conducting research that is not adequately provided by competitive and regulated markets.

Currently, the Energy Commission is managing the existing PIER Program. In 2011, the Legislature did not reauthorize the electricity research program, and the mechanism under Public Utilities Code Section 399.8 for collecting the Public Goods Charge (PGC), which funds the program, expired. Governor Jerry Brown asked the California Public Utilities Commission (CPUC) to pursue options to fund clean energy research and development (R&D) and to take

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[2] James L. Sweeney, Director of the Precourt Energy Efficiency Center, Stanford University; in a February 27, 2011, letter to Senator Alex Padilla and the Members of the Senate Energy Committee, California State Legislature.

[3] Sweeney, February 27, 2011.

into account the constructive ideas for program reform that were identified during the legislative process. The Energy Commission is optimistic that the CPUC effort or legislative action will succeed in funding energy research in the public interest. The Energy Commission is preparing for a potential successor public interest program with a renewed research portfolio to address today's energy challenges and tenuous economic conditions as well as respond to future legislative direction.

Report Structure

The Energy Commission's *PIER 2011 Annual Report* describes program accomplishments in 2011, new work initiated, and future program initiatives. This report summarizes PIER RD&D projects funded from January 1, 2011, through December 31, 2011. Chapter 1 provides a program introduction and overview of the policies guiding the Energy Commission's public interest energy research. Chapter 2 describes major research programs and highlights selected electricity research projects and their benefits. Chapter 3 discusses next steps for 2012 and the potential successor program. The Appendix contains a summary list of the electricity-funded RD&D projects that were initiated or had formal amendments to add funds in 2011.

Policy, Planning, and Program Overview

As the state's primary energy policy and planning agency, the Energy Commission makes assessments and forecasts to develop energy policies that conserve resources, protect the environment, ensure energy reliability, enhance the state's economy, and protect public health and safety. The Energy Commission sponsors RD&D to support these energy policy and planning needs and to meet the provisions of Senate Bill 1250 (Perata, Chapter 512, Statutes of 2006), and the PIER Advisory Board by focusing research intended to:

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

The Energy Commission provides research transparency, accountability, avoids duplication, and creates jobs.

Public research program administration by public agencies ensures benefits to California ratepayers by:

- Providing transparency and accountability for all funds and projects.

- Providing coordinated research to avoid duplication.
- Providing independent and impartial evaluations of proposals and projects.
- Supporting RD&D work with a statewide, policy-focused interest dedicated to benefitting ratepayers and Californians.
- Generating research opportunities for California-based companies that create jobs and stimulate the economy.
- Building long-standing relationships with California's diverse and substantial research capabilities at state universities, national laboratories, and high-tech companies.
- Leveraging funds with private sources and the federal government.
- Working with the Legislature to ensure the program is operating to fulfill statutory goals.

PIER Research Meets Policy Objectives

The PIER Program is focused on achieving critical state energy policy goals and has been guided by numerous pieces of state legislation, dating back to 1996, which have adjusted the scope of the research funded. In addition to the statutes and mandates described below, research direction is also provided in the Energy Commission's *Integrated Energy Policy Report (IEPR),* which evaluates overall supply and demand trends for electricity, natural gas, and transportation fuels in California as well as issues associated with energy infrastructure, efficiency, reliability, and cost.

An Energy-Efficient California: Energy efficiency and demand response research projects address the following state policies and goals – the CPUC Energy Efficiency Strategic Plan and IEPR 2009 (sets zero net energy goals for residential buildings by 2020 and commercial buildings by 2030), Governor Brown's Clean Energy Jobs Plan and Executive Order S-20-04 (increase energy efficiency in existing buildings), Assembly Bill 32 (Nunez, Chapter 488, Statutes of 2006) (reduce greenhouse gas [GHG] production), and SB 1250 (for example, increased energy efficiency in buildings, appliances, lighting, and other applications beyond applicable standards).

A Renewable Future: Renewable energy research is driven by a number of renewable energy generation and GHG reduction goals, including AB 32. California's aggressive Renewables Portfolio Standard (RPS) is mandated by Senate Bill 1078 (Sher, Chapter 516, Statutes of 2002) and Senate Bill 107 (Simitian, Chapter 464, Statutes of 2006), and SB 1250. In 2011, the RPS goal was increased to 33 percent by 2020 under Senate Bill x1-2 (Simitian, Chapter 1, Statutes of 2011). Renewable energy technologies will also be critical in meeting the goals of AB 32, SB x1-2, and Governor Brown's progressive Clean Energy Jobs Plan to install 8,000 megawatts (MW) of renewable central station capacity and 12,000 MW of renewable distributed generation.

A Reliable, Secure, and Smart Energy Future: Advanced generation, transmission, distribution, and smart grid research address the requirements of SB 1250 to enhance the capabilities of the

transmission and distribution system, AB 32 to advance generation to reduce GHG emissions, and Senate Bill 17 (Padilla, Chapter 327, Statutes of 2009) to implement and plan a smart grid. A smart grid is an electric grid using computers and communications to gather, distribute, and act on information about the behavior of suppliers and consumers to improve the efficiency, reliability, economics, and sustainability of electricity services.

An Environmentally Sound Energy Future: Energy-related environmental research ensures the generation, transmission, and use of energy is done in manner that minimizes impacts to California's precious natural resources, such as air quality, water, land, as well as the deleterious effects of climate change.

A Sustainable and Efficient Transportation Sector: Energy-related transportation research addresses policy goals for deploying sustainable fuels and improving vehicle efficiency as stipulated in SB 1250 and the *State Alternative Fuels Plan*. PIER energy-related transportation research also addresses statutory goals as stated in Senate Bill 375 (Steinberg, Chapters 728, Statutes of 2008) for sustainable communities.

Coordinated Efforts – Natural Gas and Electricity Research Synergies in California

In 2004, the CPUC designated the Energy Commission as the administrator of the CPUC-funded natural gas research program. The Energy Commission leverages the links between natural gas and electricity RD&D in a systems-based approach to advancing science and technology.

For example, electric research on sensors originally developed for determining the condition of electric underground cable may also be used to find welding defects in natural gas pipelines. This complementary electric research led to a natural gas research project that will use the technology advancements to sense natural gas pipeline defects.

By coordinating natural gas and electricity RD&D efforts, the Energy Commission also leverages funding, expands partners, and shares knowledge to meet California's energy goals and increase benefits for all California ratepayers. Though funding and benefits are separately tracked, integrating direct natural gas applications with electricity energy efficiency improvements (for example, building envelope measures or heating, ventilation, and air conditioning [HVAC] improvements) results in a reduction of total energy consumed and saves ratepayers money on their total natural gas and electricity bills.

As the program administrator for both the electric and natural gas RD&D, the Energy Commission coordinates and oversees funding with a variety of California stakeholders, including small businesses, universities, the California-based national laboratories, California investor-owned utilities, energy technology companies, and various advocacy groups. The Energy Commission creates and sustains these partnerships, statewide and nationally, and coordinates with these various organizations to eliminate the potential for overlap and duplication.

Program Funding Overview

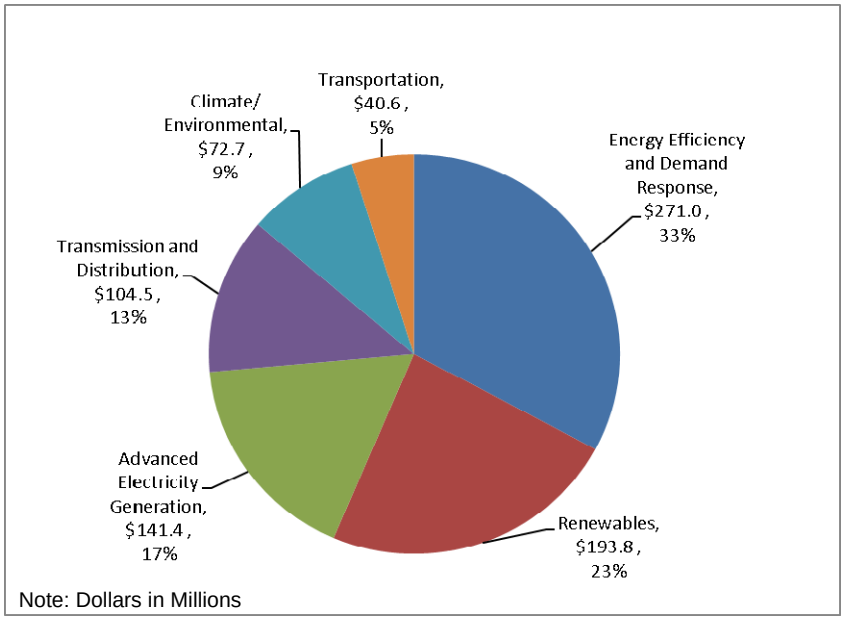
In 2011/2012, the Governor's state budget allocated the Energy Commission $31.25 million for electricity RD&D projects. In addition, the PIER Program had some 2010/2011 funds yet to be encumbered as the program has two years to encumber these funds. During the 2011 calendar year, a total of $47.18 million in electricity funds were encumbered into contracts.

Funding for energy research projects aligns with the state's Loading Order, which identifies, in order of priority, optimizing energy efficiency and demand response; meeting new generation needs first with renewable resources and distributed generation, then with clean fossil fuel generation; and improving the bulk transmission and distribution infrastructure. Figure 1 illustrates the percentage of PIER electric and natural gas allocations by research focus area from 1997 to 2011 in compliance with the loading order.[4]

Attracting Match Funding to California

The Energy Commission has encumbered more than $820.59 million for energy RD&D projects and leveraged its investments to attract more than $1.13 billion in match funding to California to date. In 2011 alone, PIER's investment of $47.18 million in electricity research funding was matched with more than $532.23 million in match funding including American Recovery and Reinvestment Act (ARRA) federal stimulus funds. Figure 2 depicts the percentage of match and research project funding in 2011. Included in the match funding are in-kind contributions, defined as noncash contributions that can be valued like money in economic terms. In 2011, PIER received numerous in-kind contributions such as software, laboratory access, equipment, engineering and consulting services, and technical support.

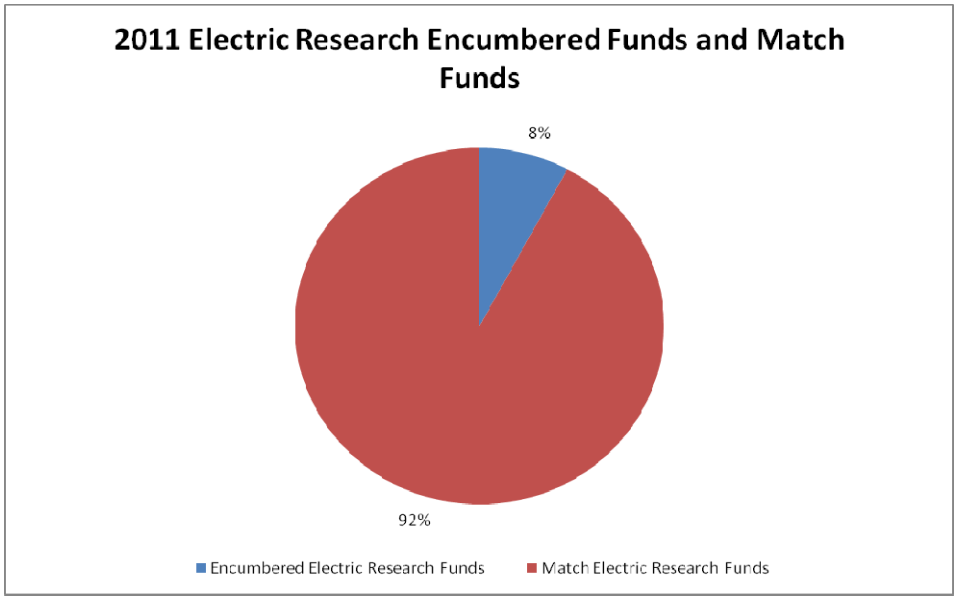
Figure 1: PIER Electric and Natural Gas Research Budget Allocations 1997–2011



Source: California Energy Commission

[4] For more information on natural gas research projects, see the 2011 PIER Natural Gas Report. Misemer, Philip and Leah Mohney. 2010. *2011 Natural Gas Report to the California Public Utilities Commission* California Energy Commission, Energy Research and Development Division.

Figure 2: Percentages of 2011 Total Electric Funding – Research and Match



Source: California Energy Commission

Creating Jobs in California

The PIER Program makes targeted investments in innovative, energy-related RD&D projects, attracts and grows businesses, and creates jobs. In the first quarter of 2011, 2,100 Californians were working in jobs directly related to active PIER-funded research. These jobs are located at research sites across the state. (See Figure 3.)

Staff estimated indirect and induced jobs using the IMPLAN® model, a widely recognized economic impact assessment software program. IMPLAN® estimates these 2,100 direct PIER-funded jobs will lead to an additional 1,250 indirect jobs (PIER contractors purchase goods and services and those suppliers then hire others) and 2,180 induced jobs (those created because the PIER contractors are spending money from their new jobs). In total, this estimates that more than 5,530 people will be employed at least part time over the course of the PIER contracts that were active in the first quarter of 2011 alone. The IMPLAN® model also estimates the collection of an additional $2.3 million in employee state and local taxes.

Figure 3: Counties with Active PIER Electricity and Natural Gas Research in 2011 (Shown in Green)

Source: California Energy Commission

In the first quarter of 2011, 5,530 Californians were working in jobs related to active Energy Commission-funded research.

The PIER Energy Innovations Small Grant (EISG) Program investment alone creates thousands of jobs in California. Awardees are expected to generate more than 12,000 direct California jobs. This estimate is based on the statistical relationship between clean technology investment and creating clean technology jobs in California. Awardees and their supply chain (developers, manufacturers, marketers, distributors, and installers) are expected to generate another 22,000 indirect jobs as they and their employees purchase goods and services.

In addition, for every $1 of PIER funding, the EISG Program has led to more than $40 in private, non-utility investment. Since 1999, awardees have garnered more than $1.4 billion in subsequent investment, including $1.3 billion in private, nonutility investment. In general, states with clean energy research funding programs like PIER attract four times as much clean technology venture capital per capita as states without such programs.[5] Applying the results of such research can lead to creating and growing new lines of business, which eventually provide private sector output and jobs.

States with clean energy research funding programs like PIER attract four times as much clean technology venture capital per capita as states without such programs.

PIER research also creates jobs by focusing on research that advances renewable energy deployment, renewable energy integration into the marketplace, and the replacement of fossil fuel generation. Researchers at the University of California, Berkeley, collected estimates related to jobs creation, and these estimates suggest that replacing fossil fuel energy generation with renewable generation will increase employment by one-half time to eight times, depending on the type of renewable generation. Similarly, replacing fossil fuel energy generation with energy efficiency measures stands to increase the number of jobs three and one half times. [6]

Program Updates and Enhancements

Over the years, the PIER Program has matured and evolved through responsiveness to stakeholder input. The sections that follow describe several recent enhancements to the program. Moving forward, these should apply to any administration of a public interest RD&D program.

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[5] Source: "Clean Energy States Alliance 2010 report: State efforts to advance clean energy." http://www.cleanenergystates.org/resource-library/resource/cesa-2010-report-state-efforts-to-advance-clean-energy.

[6] Wei, Max, Shana Patadia, and Daniel M. Kammen. 2010. "Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US?" *Energy Policy* 38, No. 2 (February): 919-931. doi:10.1016/j.enpol.2009.10.044. http://rael.berkeley.edu/sites/default/files/old-site-files/CopenhagenClimateConcill-GreenJobs-TLS-04.pdf.

Ensuring Stakeholder Participation Through the Advisory Board and Program Advisory Groups

The governance structure for PIER is defined by statutory requirements and includes a stakeholder Advisory Board to provide such strategic advice and feedback on program direction and research initiatives.[7] The membership of the PIER Advisory Board, as required by statute, includes Legislative members, energy agencies, utilities, and environmental, consumer, and business organizations.

The Energy Commission selected the PIER Advisory Board members based on these criteria:

- Desire for balanced and diverse membership
- Policy-level or senior-level research expertise
- Special or unique knowledge or relevant experience
- Ability to participate in the dialogue on California's RD&D priorities and future program directions
- Degree of personal commitment
- California-based company or presence
- Organization's perspective on energy RD&D

Members of the Advisory Board are not authorized to make decisions but act as valuable advisory members. Members are subject to the Political Reform Act, which bars them from making program decisions, selecting research awards, entering into or negotiating contracts, or otherwise performing duties on behalf of the Energy Commission.

During 2010 and 2011, the Energy Commission held three publicly noticed Advisory Board meetings. In addition to the Advisory Board, the Energy Commission also formed Program Advisory Groups (PAGs) to focus on three research program areas – Energy Efficiency, Renewable Energy, and Energy Infrastructure (that is, smart grid, some energy-related environmental research, and transportation). The purpose of the PAGs is to improve transparency of research priorities and funding decisions and increase stakeholder input. These PAGs provide a public forum for reviewing budget plans, developing new program initiatives, and making recommendations to the PIER Advisory Board on how to ensure relevancy of research initiatives, find synergy and end-user opportunities, and avoid overlap and duplication with the research agendas of others. Membership of the PAGs includes the utilities; nongovernmental organizations; government agencies, especially the CPUC, California Air Resources Board (ARB), and the California Independent System Operator (California ISO); manufacturers; end-users of energy services and technologies; and representatives of the general public.

[7] California Energy Commission, Charter for the PIER Advisory Board, November 10, 2010.

In 2011, the program responded to stakeholders, including those suggesting a narrower program focus that reduces transportation and environmental research (particularly climate change research). These stakeholders question the electricity ratepayer benefits of these areas, while others contend that the consequences of energy generation and use's contributions of GHG emissions more than justify the research to ameliorate these effects. In 2011, the PIER Program narrowed the scope of research in these areas while still meeting current statutory requirements. New environmental and transportation projects must have a compelling and direct energy nexus. This has created a void in vital research for California. While this research has been instrumental to California in forming policy and providing mitigation and adaptation strategies to reduce impacts from energy-related climate change projections and vehicle emissions, other sources of funding will likely be necessary to continue such public interest research.

Any public interest energy RD&D program that is funded using ratepayer dollars needs to demonstrate a reasonable probability of achieving ratepayer benefits in the selection of RD&D projects for funding.

Communicating Public RD&D Benefits

Any public interest energy RD&D program that is funded using ratepayer dollars needs to demonstrate a reasonable probability of achieving ratepayer benefits in the selection of RD&D projects for funding. The program developed a program-wide approach to benefit and cost assessment, which includes integrating benefits assessment elements into work plans and databases, evaluating interviews and surveys, identifying required benefits metrics, and requiring researchers to provide a subsequent report on these metrics. A public workshop in 2011 was held to vet the methods and brought together benefits analysts and practitioners from state and federal agencies, academia, research institutions, and the public.

PIER's benefits assessment method involves collection of pertinent data needed for benefits analysis throughout the research project development, award, and management stages. In 2011, the method was examined and vetted at a benefits-focused workshop, which was attended by experts in field, including representatives from New York State Energy Research and Development Authority.

Energy Commission staff conducts the following research benefits assessment activities starting with work planning and preparation of solicitations and continuing on through to contract closure:

- Documenting the energy use sector addressed by the planned research, the energy use in that sector, and how much the energy use can potentially be reduced
- Requiring potential benefits assessment data, market projections, and price projections where practicable from solicitation bidders and contractors
- Requiring that bidders include details on where the research will be done and any known geography of expected benefits

- Collecting benefits metrics (for example, energy saved, jobs created, renewable generation costs lowered) during the contract through interim and final reports and updates after project closure
- Interviewing contractors to determine representative quantitative and qualitative benefits and appropriate metrics to estimate, analyze, and report
- Consulting with technical staff and relevant data sources to further evaluate data gathered from contractor interviews and reports
- Documenting all steps of estimation and transparently presenting uncertainties
- Evaluating the proportion of estimated benefits attributable to PIER
- Seeking peer review of benefits estimations
- Analyzing the cumulative effects of benefits data in the context of other related research

Enhancing Public Outreach: Publications and Research Forums

The Energy Commission has considerably expanded outreach and dissemination of research information to the public by streamlining the publication process for disseminating project results. In the last year, nearly 100 reports and fact sheets were released. To communicate the program's successes, the Energy Commission published a brochure, *PIER: How Public Research Powers California*, and prepared other brochures targeting success in specific topic areas such as overcoming renewable energy barriers, importance and benefits of energy efficiency research, and research investments and the resulting impacts on jobs.

The Energy Commission staff held several research forums in 2011 to share project results, promote collaboration, and seek input on most valuable next steps, including:

- *Venture Capital Forum*
- *Solar and Wind Forecasting: Achieving a 33 Percent Solution*
- *Research Topics for Building Energy Efficiency Solicitation*
- *Indoor Environmental Quality Research Roadmap*
- *2011/12 PIER-Related IEPR Workshops*
- *Research to Assess and Reduce Impacts of Energy Infrastructure on Wildlife*
- *Joint Efficiency Workshops With the CPUC on the Research and Technology Action Plan*
- *2011/12 PIER Initiatives to the PIER Advisory Board and PAGs*
- *PIER Benefits Assessment Workshop*
- *PIER Desert Research Related to Energy Siting and the Desert Renewable Energy Conservation Plan*
- *2011 Renewable Energy Secure Communities (RESCO) Experts Symposium*
- *2020 Strategic Analysis of Energy Storage in California*

- *Webinars on Building Energy Efficiency Highlighting PIER Activities*
- *Webinar on Developing Energy-Efficient Communities: The Chula Vista Case Study*
- *Webinar: Up on the Rooftop: Updating HVAC Rooftop Unit Performance*
- *Sustainable Communities Focus Area Brownbag Lunch Series:*
    - *Assessing New Transportation and Urban Development Patterns in a Climate-Constrained Future*
    - *Life Cycle Energy Assessment of Community Design Changes, Methodology to Develop Energy Baselines for CA Regions and the Proposed CA Center for Sustainable Communities at UCLA*
    - *Life Cycle Assessment of Community Design Changes: Energy and Environmental Assessment of the Los Angeles Metro's Orange (Bus Rapid Transit) and Gold (Light Rail) Lines*

Such research forums and public outreach events received substantial positive stakeholder feedback, and the program plans to hold additional forums in the future.

Contract and Solicitation Reforms

The Energy Commission has undertaken a comprehensive review of contracting using a multi-pronged approach: investigating within PIER, examining procedures throughout the Energy Commission, and dialoging across state agencies. For example, the program made a valuable process reform to use simpler budget forms following feedback and challenges reported by contractors. The program is also working to make administrative changes to reduce the number of formal contract amendments, hold contractor training workshops to increase efficiency, increase the number of privately targeted competitive solicitations, and reduce the use of sole source contracts.

Ensuring Direct Funding to California and Revising Solicitations

The PIER Program responded to comments by the Legislature and others by revising the research solicitation process and proposal selection criteria, requirements, and scoring to effect the following changes:

- Higher preference to California-based entities
- More PIER funds spent in California
- Controlled overhead and general administrative costs (higher points for proposals with lower loaded rates)
- More public events held early in the solicitation process

Intellectual Property Rights Review

Intellectual property (IP) refers to products of the mind that the law protects, such as copyrights, trademarks, and patents. The treatment of IP rights under an RD&D program will affect the program's success. The Energy Commission manages IP rights for the PIER Program by requiring contractors who sell IP products developed with PIER funds to pay royalties. In 2011, the Energy Commission took steps to increase the collection of royalties. These steps included strengthening the PIER terms and conditions regarding royalties, conducting royalty payment verification reviews, and contacting contractors to determine whether royalty payments are owed. The Energy Commission is also in the process of obtaining a contractor to perform follow-up calls and independent market assessments on PIER contract and grant recipients who may have sold IP products and not yet paid royalties.

CHAPTER 2:
PIER's 2011 Research Delivers Ratepayer Benefits

In 2011, the Energy Commission funded RD&D that will address and remove barriers to achieving the state's energy policy goals. This chapter provides overviews of the PIER Program's three major research program areas: energy efficiency, renewable energy, and energy infrastructure. It includes a short description of each program area followed by illustrative 2011 research project highlights, which describe the issue addressed, project details, purpose, findings, and benefits. Research highlights for projects completed in 2011 (and some in-progress projects) describe significant results and conclusions. Summaries for newly initiated projects and some in-progress projects include preliminary results and significant milestones or issues addressed in 2011.

Energy Efficiency Research

As California's population grows and the demand for energy increases, energy efficiency continues to be an important strategy for containing energy demand and GHG emissions for the building and industrial, agriculture, and water sectors. These sectors consume more than 90 percent of the state's annual electricity or more than 264,000 gigawatt hours (GWh) annually. 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.[8] Continued development, enhancement, deployment, and operation of better energy efficiency-related technology for existing and planned buildings and industrial facilities and processes are essential to meeting the state's energy efficiency and GHG reduction goals. RD&D is focused on developing technologies, strategies, models, or tools to reduce energy use in the buildings, industrial, agriculture, and water sectors.

Buildings End-Use Efficiency Research

Electricity use in residential and commercial buildings accounted for 69 percent of the approximate 286,000 GWh of electricity consumed in California in 2008. Improving the energy performance of buildings and appliances is a key to achieving the state's major policy goals of energy efficiency and reducing GHG emissions.

The buildings end-use efficiency program sponsors research leading to cost-effective performance and energy efficiency improvements in buildings, infrastructure (such as street and parking lot lights), equipment, appliances, and consumer electronics. The program focuses on the major energy using systems, including lighting, HVAC, and consumer electronics (plug loads), and targets the following:

- New and improved products

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

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

New and Improved Products for California Consumers

Developing Plug-Load Solutions in California

The Issue: Plug-load devices include consumer and office electronics, appliances, and some tools – virtually anything that plugs into an electrical outlet and uses some form of low voltage direct current power. They are responsible for as much as 20 percent of the electrical consumption in buildings and by 2030 are expected to account for about 30 percent. If not well-managed, plug loads could reverse California's efficiency goals and hamper California's plans for zero net energy in new homes by 2020 and commercial buildings by 2030. Research is needed to increase the energy efficiency of plug-load devices to control and minimize energy use in a safe, cost-effective, and environmentally sound manner.

The Research: In 2011, PIER initiated a contract with the UC Irvine's Plug Load Research Center (CalPlug Center) to investigate the issue of plug-load entertainment devices, such as set top boxes and appliances, and plug-load energy efficiency standards and policy. The center will collaborate with research institutes and manufacturers and assist in developing future appliance efficiency standards and other efficiency improvements to reduce electrical consumption. One of the first areas of research involves set-top boxes, such as cable or satellite boxes. These boxes can use nearly the same amount of energy whether they are on or off. Two boxes use the equivalent of a 10-year old, 19-cubic-foot refrigerator/freezer.[9] Research will focus on how to put these devices in light sleep mode using minimal energy (for example, less than 5 watts) without affecting customers.

Figure 6: Example of Typical External Power Supply Use

Source: Pacific Gas and Electric

In addition, the New Buildings Institute completed research in 2011 documenting plug energy use in buildings that were considered very energy-efficient (high performance buildings). In this project, the baseline energy consumption of plug-load devices was measured in an office and a library in California. Based on findings from inventory of plug-load devices and initial metering, the researchers next installed low- and no-cost energy reduction strategies on a subset of plug-load devices and retested plug load energy consumption on the affected as well as the unchanged devices for an additional month. Researchers then compared the electricity consumption of the affected plug loads to the baseline data to quantify the energy savings of various measures.

[9] Calculated assuming 19-20 cubic feet, top and bottom refrigerator-model year 2000 to 2008: http://www.energystar.gov/index.cfm?fuseaction=refrig.calculator&screen=1.

The Benefits: Plug load research will result in the development of new, more energy-efficient technologies, devices, and standards that maximize energy efficiency, especially when devices are not in use. These will be done collaboratively with manufacturers and industry. Past research efforts have led data analysis that contributed to the Energy Appliance Standards (Title 20) for televisions, external power supplies and battery chargers. These projects resulted in saving Californians more than $1 billion per year after installation of these measures. Once research at the CalPlug Center on set-top boxes is complete, it is anticipated that this research could result in reducing set-top box energy use by at least 75 percent annually.[10] The New Buildings Institute research of office plug load identified several strategies that could reduce annual energy use in the two tested buildings by 17,450 kilowatt hours (kWh) without hardware replacement and up to 78,480 kWh with replacement. These findings suggest savings opportunities and for plug load energy reduction even in high-performing buildings. Strategies recommended include:

- Software Power Management Settings – Enabling and properly programming existing power management settings of computers and imaging equipment provides the largest energy savings opportunity.
- Hardware Control Strategies (Timers and Advanced Plug Strips) – Several control strategies can be employed to turn off devices when not in use and significantly reduce energy consumption, but this benefit must be weighed against the cost of purchasing and installing these control strategies.
- Occupant Behavior Measures – Even the easiest and least expensive behavioral measures, such as sending an e-mail calendar reminder encouraging employees to turn off equipment at night and on weekends, has notable savings.
- Hardware Equipment Replacement – Swapping out older, inefficient, or overpowered equipment for newer hardware can lead to reduced power consumption. For example, electricity use of an occasionally used, inefficient desktop computer was reduced by 95 percent by replacing it with a microsized desktop with basic functionality, ultra-low power use, and power management settings enabled.

The New Buildings Institute project approach and results were shared via an Internet webinar that was attended by 234 attendees from across the country. During the webinar, researchers identified specific savings opportunities and actions that building owners, utilities, and policy-makers can take and what kind of percentage savings to expect from implementing these actions in commercial buildings. Attendees and researchers suggested that follow-up research would be valuable and that it should be expanded to include a wider variety of miscellaneous devices in more building types and increase the sample sizes of the devices that are metered. The Energy Commission staff will discuss these recommendations with its own Information

[10] Estimated assuming average set top box energy use is 20 watts and operates 8760 hr/yr resulting in 175 kWh/yr. A 75 percent reduction will result in savings of 130 kWh/yr or about $20, assuming $0.15/kWh. Also, http://www.nrdc.org/energy/files/settopboxes.pdf.

Technology (IT) Branch to see whether they can be implemented in the future. The staff plans discussions with representatives of the California Department of General Services who attended the webinar and expressed interest in the recommendations.

Lighting Demonstrations Cut Electricity Costs

The Issue: Lighting annually consumes about 22 percent of residential building electricity use and roughly 35 percent of commercial building electricity use. This accounts for about 42,000 GWh of power consumption annually or about 15 percent of California's electricity consumption. Substantial reductions in lighting energy will occur only if gaps to research, development, and demonstration are addressed, and barriers, such as lack of customer awareness and knowledge, are overcome. Two ways to reduce energy use include increasing the efficiency of the light source and/or restricting the lighting's operating hours to only the times when lighting is needed. New technologies, developed through PIER, address both of these areas, but demonstrations are needed to justify benefits and savings before there is widespread acceptance for doing large-scale retrofits.

Figure 4: Bilevel fixtures with Occupancy Sensors Installed in City of Sacramento Parking Garages

Source: Case Study for Bilevel Lighting, Energy Upgrade California

The Research: Through the Statewide Partnership for Energy Efficient Demonstration Program and the Energy Technology Assistance, several lighting demonstrations were installed in 2011. These demonstrations include energy-efficient luminaires and advanced lighting controls, which were developed directly with PIER funding as well as derivative products that have their origins in PIER-funded projects. Derivative products are equivalent products from new manufacturers, newer versions of products that were improved as a result of information obtained through demonstrations, or new classes of products designed for new applications revealed through the demonstration process. The lighting technologies demonstrated include solid-state lighting, such as light–emitting diode (LED) down lights, bilevel luminaires, exterior wall fixtures and free-standing walkway lights (for example, bollards); adaptive lighting, which incorporates both high-efficiency luminaires with integrated occupancy/daylighting controls for

corridors; bilevel stairwell with fluorescent fixtures, wireless lighting controls, integrated office and classroom lighting systems, plasma luminaires, and bilevel induction luminaires.

The Benefits: The resulting demonstrations were extremely successful and have cut electricity costs in California's public colleges, local governments, and a military base by more than 810,000 kWh or a reduction of about 300 metric tons of carbon dioxide (CO_2) emissions. In addition, these projects resulted in annual cost savings of nearly $100,000. [11] These savings continue to accumulate each year. In addition to reducing operating cost, these projects also demonstrated the benefits of the project to the operators and showed how good lighting can still be energy efficient. For instance, the operators of the parking garage in Sacramento were so impressed with the lighting and the energy savings that the city will retrofit the remaining seven garages. Once complete, these lights will save the city more than 4 GWh annually and reduce annual electricity expenditures by about $470,000. The simple payback is estimated to be less than three years. Once the savings have paid off the project, the city will now have $470,000 more to spend on city operations, rather than on electricity bills.

> *"Initially I was leery about the bilevel feature. The idea of reducing light levels when no one is around makes a lot of sense, but I was concerned that at half power, the area would appear dark and uninviting. The demo really changed my mind – at half power there was ample light and seeing the fixtures brighten in front of you as you walk creates a really positive feeling."*
>
> *Matt Eierman, City of Sacramento Parking Facilities Manager*

Saving Energy With Personal Interior Temperature Controls

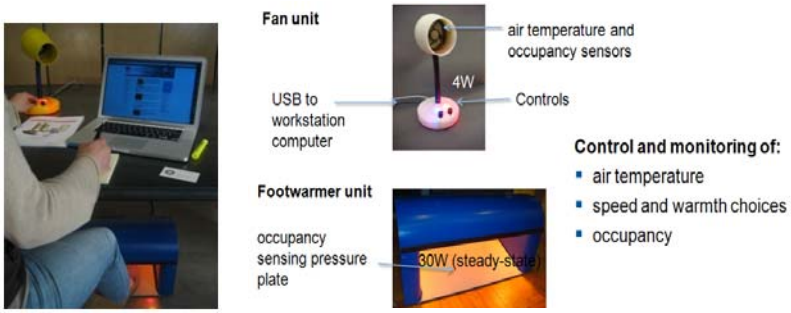
The Issue: Personal control over task lighting is a natural and relatively easy energy efficiency measure to provide in modular furniture. Personal control over ambient temperature, where occupants may be in open plan offices, is much more challenging.

The Research: The UC Berkeley Center for the Built Environment developed a project that deployed personal environment equipment in 2011 that provides individual comfort using a small fan or a low-wattage foot warmer or hand warmer. The personal environmental equipment enables local control for each individual, regardless of the settings of neighboring equipment. This enables energy savings by allowing the general interior temperature of a building to swing over a larger range, while maintaining each individual's comfort.

The Benefits: Small devices that warm only the feet or hands or that provide gentle air movement can more than compensate for building interiors that are cooler in winter and

[11] Assumes 0.000377 metric tons per kWh saved and 0.01 metric tons per therm saved (California Air Resources Board, 2012). Also includes energy savings from Energy Upgrade California projects in the City of Pleasanton, San Diego State University, UC Berkeley, and City of Sacramento.

Figure 5: Personal Environment Equipment



Source: University of California, Berkeley Center for the Built Environment

warmer in summer. For example, reducing building thermostat temperature by 2.7 degrees F (1.5 degrees C) in San Francisco in the winter corresponds to 10 percent heating energy savings. Cooling energy savings are even larger, with a 1.8 degree F (1 degree C) increase in thermostat temperature corresponding to nearly 15 percent cooling energy savings. To date, PIER funding has provided for development and manufacture of 100 combination personal heating and cooling systems, which provide a user-controllable foot warmer for heating and a tiny breeze-inducing fan for cooling. Further work will engage industrial designers and furniture manufacturers to integrate the concepts into aesthetic designs. The U.S. General Services Administration is interested in testing them in federal government buildings. When fully developed, these devices could provide enhanced comfort for millions of office workers nationwide, along with large energy savings. Potential cooling energy savings in California office buildings is estimated to be more than 1.8 GWh (greater than 678 metric tons of CO_2 reduced) with over 1.5 GW demand savings.

Energy-Efficient Designs, Materials, Building Techniques, and Tools

Best Practices for Home Energy Retrofits in California

The Issue: Effective home energy retrofits require an understanding of building science, design principles, and the ability to measure and verify energy savings. Home performance contracting, when done right, provides homeowners with better comfort, better indoor air quality, and a safer, more durable home that uses less energy. This is done through measured results of home performance versus hoped for benefits. The true application of home performance contracting is unclear to many contractors and installers, and not all companies that advertise "home performance" are in fact measuring the results of their projects.

The Research: In 2011, the Gas Technology Institute, Chitwood Energy Management, and Mason Grant Consulting, teamed together to produce a guide on home performance contracting titled *Best Practices Guide to Integrated Energy Design and Installation*. The guide is directed at contractors and installers and explains the principles of home performance contracting and best practices, which result in proven energy savings for homeowners and profits for contractors. The recommendations are based on actual cost-effective retrofits with measured savings for typical single-family homes in California.

The Benefits: This project has already resulted in a book titled *Measured Home Performance, Guide to Best Practices for Home Energy Retrofits in California*. This book is a best practices guide for energy efficiency retrofits for homes that will help practitioners in improving the quality of construction. The measures outlined in the guide are aimed at reducing annual heating and cooling costs by 40 to 60 percent in addition to improvements in occupant comfort.

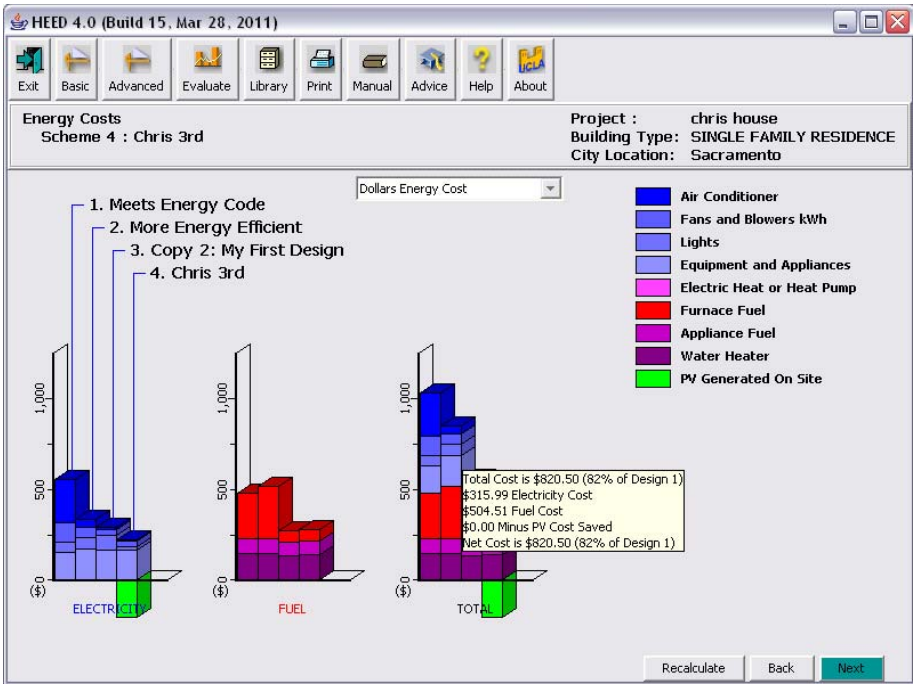
Modeling Software Helps Designers Plan for Residential Energy Efficiency

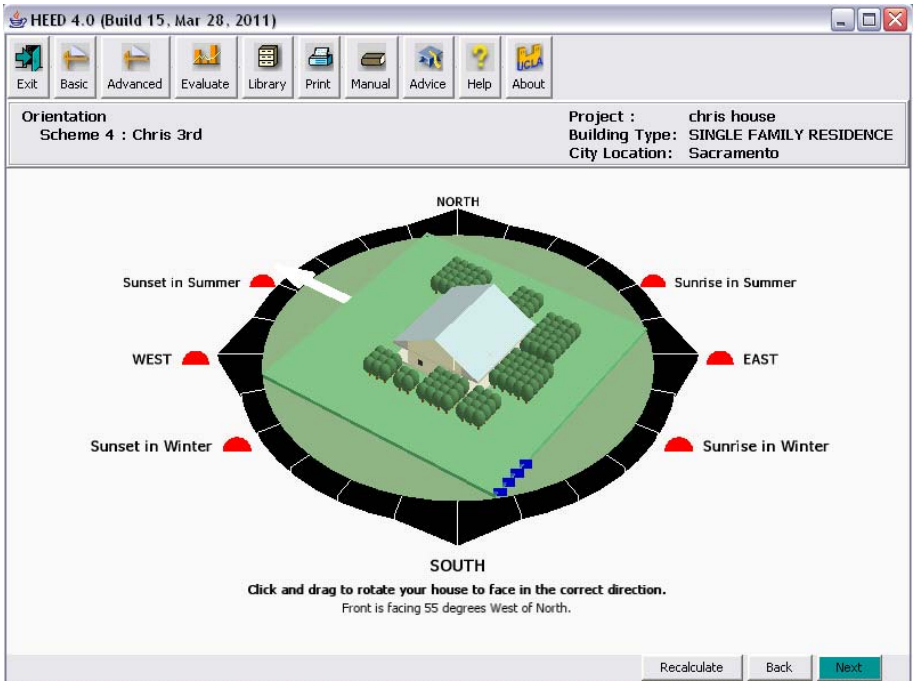
The Issue: Meeting California's energy efficiency goal of zero net energy buildings by 2020 requires important decisions on building energy use at the design phase. Most small architecture firms and residential designers have never had immediate feedback on the energy and comfort effects of design decisions, including such features as the size, type, and orientation of windows, insulation levels, and shading. As a result, important design decisions are usually made without vital energy use data.

The Research: UCLA architecture professor Murray Milne and CSU Pomona professor Pablo LaRoche, using PIER funding in 2011, refined and improved an easy-to-use software simulation tool for architects to use when designing or renovating homes. The software, called Home Energy Efficient Design (HEED), allows users to see how much energy, money, and carbon can be saved by making various design or remodeling changes. The program now allows users to include the actual floor plan, window location, wall and roof construction details, renewable energy components, and cool roofs. The program includes the current California Energy Code and includes the latest utility rates. There is even a screen for determining each design's zero net energy rating and zero net carbon rating as a percentage of the reference code compliant building.

The Benefits: The tool accurately calculates energy use for space conditioning, lighting, and hot water production. It even predicts thermal comfort at various times and dates within the building. Changes can easily be made and compared with previous configurations as the building design is developed. The tool can be downloaded for free and is so easy to use that an owner, amateur builder, or remodeler can quickly gain expertise with it and determine how much energy and money can be saved by making various design or remodeling changes to a home. This software tool fills an important gap in the marketplace and will help California to reach its goal of zero net energy homes by 2020. Downloads of the tool have totaled more than 45,000 since this project began. In other words, the program has had an increased user base of more than 45,000, which is directly related to PIER support.

Figure 7: Example of Home Energy Efficient Design Software Output





Source: http://www.energy-design-tools.aud.ucla.edu/

Reducing Energy Use in Commercial Rooftop HVAC Units

The Issue: About 60 percent of commercial buildings in California use rooftop HVAC units, also known as RTUs, for heating and cooling, and it is estimated that as much as 70 percent of these require some level of maintenance to function at anywhere close to their rated efficiency.

Figure 8: Rooftop HVAC Unit

Source: http://tassiotemp.com/home/index.php/commercial-hvac/commercial-rooftop-installations/

The Research: Fault detection and diagnostics (FDD) enables automatic detection and diagnosis of equipment faults, sensor failures, and control errors in HVAC systems. The FDD software uses existing sensors and controller hardware to detect and diagnose deviations between actual and optimal HVAC system performance.

The New Buildings Institute completed a PIER project in 2011 that developed a standard to identify the minimum performance problems FDD should detect for commercial building HVAC rooftop units and accurately detect the problems and remotely communicate them to building owner or maintenance personnel in an effectively and quickly.

The Benefits: Minimum FDD standards to identify HVAC RTU performance issues for low air flow, economizer malfunction, and faulty sensor problems will be in the proposed 2013 Title 24 Standards.[12] This will reduce annual energy use and costs for building owners and operators and can alert them when maintenance and equipment problems occur. This latter feature could reduce time spent by maintenance staff on building occupant complaint calls. The FDD software can turn a routine evaluation into a money saver for building owners. Implementing the minimum FDD standards into the upcoming energy code will save building owners/operators an estimated 2.1 GWh (roughly 792 metric tons of CO_2) annually.

Improving Efficiency in New California Homes

The Issue: To develop Building Energy Efficiency Standards that effectively reduce end-use energy consumption and peak electrical demand, it is necessary to know the baseline energy efficiency characteristics of homes currently being built. However, there is a lack of knowledge about the characteristics of recently constructed new homes, particularly the multifamily homes (that is, flats, townhomes, rental homes, and owner-occupied homes). In these homes there are

[12] "2013 California Building Energy Efficiency Standards: Light Commercial Unitary HVAC."(http://www.energy.ca.gov/title24/2013standards/prerulemaking/documents/2011-04-27_workshop/review/2013_CASE_NR7_HVAC_Controls_and_Economizing_2011_04_20.pdf).

opportunities for additional energy efficiency gains for new home construction. Improvements in multifamily homes also will assist renters whom are often lower income and most benefit from efficiency savings.

The Research: To obtain baseline data, 80 single- and multifamily low-rise homes built under the 2005 Standards were surveyed to determine how well these homes met the intent of the standards. The results of the research, which was completed in 2011, indicated that 78 percent of the lighting wattage in single-family homes and townhomes was incandescent. Seventy-five of the 80 homes (94 percent) had formaldehyde concentrations higher than the Chronic Reference Exposure Level. The average air conditioner performed well below expectations. HVAC tests revealed multiple problems, including low efficiency. The problems were particularly severe in zoned systems and in combined hydronic (water) systems.

Figure 9: Assessing Energy Efficiency in Newly Built Homes

Source: http://www.toptennewhomecommunities.com/blog/calif-tract-housing-goes-energy-efficient/1490

Single-family homes were found to be reasonably airtight, but 51 percent of the leakage area was between the attic and occupied space for homes with attached garages and accessible attics. In the second phase of the research, upgrades on nine HVAC units resulted in an average efficiency improvement of 24 percent and improved indoor air quality – by lowering formaldehyde levels through better insulation.

The project resulted in 16 recommendations for improvement to Title 24 Standards and additional field research associated with air flow, HVAC, duct leakage, furnaces, Home Energy Rating Systems inspections, house air leakage, location of condensing unit vents, building leakage, and other areas.

The Benefits: The project resulted in 16 recommendations for changes to the 2013 Title 24 Standards. These changes will improve the energy performance of homes, reduce heating and cooling energy use, lower energy costs, and improve indoor air quality in future homes constructed and renovated in California.

Industrial, Agriculture, and Water End-Use Efficiency Research

The industrial, agriculture, and water (IAW) sectors in California use 30 percent of all electricity consumed annually in the state.[13] 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

[13] 2011 Emerging Technology Demonstration Grant Program Solicitation, PON-11-501, revised October 2011.

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.

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 process 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

Reducing Air-Conditioning Energy Use and Cost in Data Center Operations

The Issue: Data centers are significant consumers of electrical energy in California, consuming an estimated 3 percent of the state's electricity.[14] If energy efficiency improvements are not made for data centers, electricity consumption will double every five years.[15] Within the data center, one of the main areas of energy consumption is cooling. Cooling consumes between 30 and 50 percent of the data center's energy use. Data center operators often conservatively over-cool buildings in a desire to protect expensive IT equipment. That excessive cooling constitutes a large portion of data center energy use, so this situation presents an energy- and cost-saving opportunity.

The Research: The Energy Commission cofunded a project that was successfully completed in 2011 and demonstrated Vigilent's technology in eight State of California data centers that were of widely varying sizes, ages, and types.

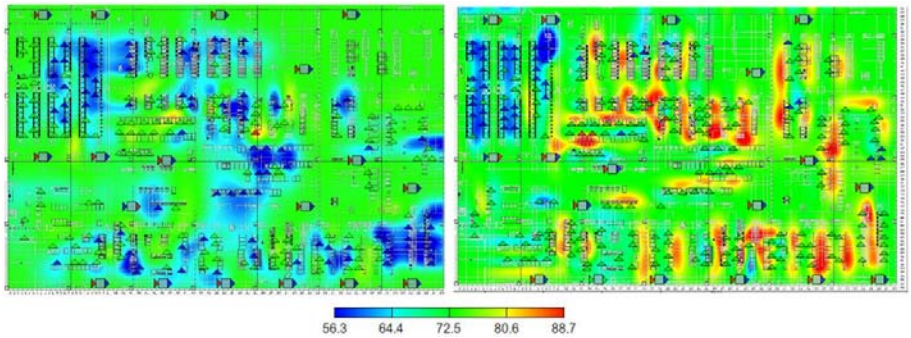
The Benefits: Research results for these eight data centers showed that Vigilent's intelligent energy management system and related energy alterations resulted in more than 2.3 GWh (867

[14] Calculated from information contained in "EPA Report to Congress on Server and Data Center Efficiency," Public Law 109-43, and extrapolated for California.

[15] Ibid.

metric tons of CO_2) in cooling energy savings annually (an almost 41 percent reduction of cooling energy), and saved the state more than $240,000. The artificial intelligence system that drives the active, dynamic control of the cooling units uses data collected from temperature sensors, as well as historical data to learn the relationships between cooling equipment and the IT load. The system ensures data center reliability and minimizes cooling energy consumption. Vigilent's intelligent energy management system is now used in over 2 million square feet of data centers.

Figure 10: Left: Data Center Thermal Map Before Vigilent's Active Controls Went Live; Right: Data Center Thermal Map After Vigilent's Active Controls Went Live, Reducing Overcooling While Protecting IT Equipment



Source: "Recovery Act: Federspiel Controls (now Vigilent) and State of California Department of General Services Data Center Energy Efficient Cooling Control Demonstration" PIR-10-052 Final Report http://www.osti.gov/bridge/product.biblio.jsp?query_id=0&page=0&osti_id=1025751&Row=0&formname=basicsearch.jsp

Volume Server Research Yields Substantial Power Reduction for Data Centers

The Issue: As stated earlier, if energy efficiency improvements are not made for data centers, electricity consumption will double every five years.[16] In addition to air conditioning, servers are big energy users. Within the data center, the most common servers used by the industry (called volume servers) consume 68 percent of the energy.[17]

The amount of electricity the SeaMicro device can save is equivalent to a city of about 570,000 people – such as Fresno or half of San Jose.

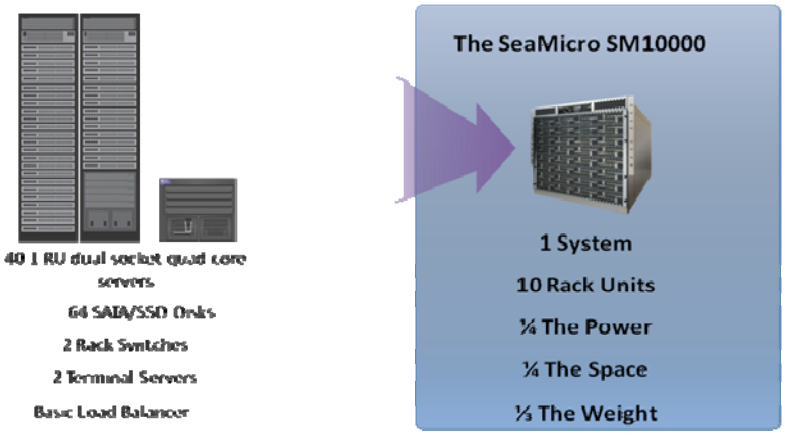
The Research: In 2011, SeaMicro, Inc. developed a game-changing device that addresses an inherent inefficiency of volume servers. The computing device replaces energy-intensive, multi-core central processing units (CPUs) that are used in volume servers with small, low-energy CPUs better suited for the Internet, like those commonly found in cell phones and hand-held devices. The smaller CPU and other improvements to server technology reduce the server size from a pizza box to a credit card. The smaller

[16]Calculated from information contained in "EPA Report to Congress on Server and Data Center Efficiency," Public Law 109-43, and extrapolated for California.

[17] http://www1.eere.energy.gov/manufacturing/datacenters/pdfs/seamicro_power_reduction_ppt.pdf.

servers are linked together by a fabric within the computing device that will provide equivalent computing power of a standard server rack.

Figure 11: The SeaMicro Device



Source: SeaMicro, Inc.

The Benefits: The computing device will use one-fourth the energy and is one-fourth the size of a standard server rack. These improvements have the potential to reduce annual energy used by data centers in California by more than four billion kilowatt-hours (kWh) (1.5 million metric tons of CO_2).[18] This is equivalent to the annual electricity use of about 570,000 homes in California.[19] The figure shows that the SeaMicro device (the SeaMicro SM10000) provides the same computing capacity as two traditional server racks containing 40 servers and 64 disk drives and uses only one-fourth the energy and space and one-third the weight.

This innovation was funded in part by a PIER grant of $250,000. This was used as match funding for a DOE ARRA grant of $9.3 million and other funding totaling more than $10 million. SeaMicro has also received more than $40 million in venture capital.

Renewable Energy Research

Renewable resources are essential for reducing GHG emissions and reaching state energy goals. The PIER Renewable Energy Program has been conducting research and development that addresses key technological, performance, and integration barriers of core renewable resources such as biomass, solar, wind, and geothermal energy. Recently, research emphasis was placed on accelerating the deployment of multiple renewable energy conversion technologies at key market scales such as utility and localized power generation. This shift in focus will help increase reliable access to renewable energy, reduce technology integration barriers, improve renewable energy forecasting and storage, reduce the cost of renewable energy, and optimize infrastructure investment. This strategy can also help close the gap in research for the deployment of renewable energy technologies and accelerate system integration.

California's long history of environmental leadership and responsibility in its energy sectors continues to be driven by a commitment to protect land, air, and water quality and reduce dependence on foreign oil. California's aggressive yet forward-thinking energy policy goals, namely the RPS and GHG reduction targets, are rooted in environmental protection. The

[18] Based on 75 percent of the 6.12 billion kWh/yr used by volume servers.

[19] Assumes the average home uses about 7,000 kWh annually.

environmental program funds RD&D to address such obstacles related to renewable energy deployment.

Comprehensive Concentrating Photovoltaic Makes Solar Energy More Cost-Effective

The Issue: Several factors inhibit the potential growth of the California photovoltaic (PV) market: high installation costs, expenses related to system components, and traditional solar designs that limit installation locations. Many improvements have been made in recent years on the assembly and deployment of flat-plate PV technologies. However, installation and multi-vendor assembly costs remain a large and complicated component of the installed cost for a full system. New concentrating PV technologies promise to reduce total cost while offering higher energy production. However, most systems fall short with incomplete and expensive offerings. Until PIER funded this project, no solar company provided a complete PV or concentrating PV comprehensive solution.

Figure 12: GreenVolts' Concentrating Photovoltaic System Installed in Fremont, California

Source: GreenVolts, Inc.

The Research: The aim of this project was to demonstrate installation cost reductions, low-cost manufacturability, technical performance improvements, and reductions in ground footprint, which will allow for minimal disturbance of soil and ecosystem, in a PV system. In 2011, the project completed such development and demonstration, providing a comprehensive package of a new concentrating PV system that reduces system costs and supports California's increased reliance on renewable energy as a GHG reduction strategy.

The Benefits: The Green Volts concentrated PV system is designed for rapid deployment and simple assembly, and due to its scalable nature, it can be used for distributed near-load locations, as well as scaled up to multi-MW, utility-scale power plants. One substantial ratepayer benefit is that this has significantly reduced installation costs and increased the number of deployment sites, serving the commercial, industrial, agricultural, and wholesale (utility) markets. An additional benefit of the dual-axis tracking is the increased generation closer to peak, when it is more beneficial to generate electricity.

The new system is now in full production with about 0.5 MW from six installations in California and Arizona. In 2011, multiple sites were in development with capacity ranging from 200 kW to 1 MW. In addition, the first solar concentrating PV power purchase agreement was signed by Pacific Gas and Electric Company for a 2.5-MW power plant near Tracy, California.

Success of the project also stimulated infusion of new investments into California. On December 14, 2011, Dow Jones announced that ABB, the global power and automation technology group, has agreed to invest about $20 million as part of a $35 million financial round for a substantial

minority stake in GreenVolts, Inc. Through the investment, ABB can now offer fully assembled and quickly installed solutions for concentrating PV power plants in addition to its current capabilities in solar thermal and conventional PV power plants.[20]

Renewable Energy Technology to Provide Energy Security and Prosperity in Humboldt County

The Issue: The need for locally generated electricity is particularly important in remote rural locations, such as Humboldt County, where electricity and natural gas transmission issues are prevalent. While the peak electricity demand of Humboldt exceeds 160 MW, the total transmission capacity is only about 70 MW. Furthermore, the tools and models needed for Humboldt County to implement an optimum, locally-available community energy portfolio did not exist before this project.

The Research: The Humboldt County Renewable Energy Secured Community (RESCO) project is developing the necessary steps toward accelerating the use of renewable energy technologies needed to supply electricity to the community. These steps include preparing the tools, models, and planning methods necessary to generate a majority of its energy needs from locally available renewable resources. In 2011, the project completed a comprehensive economic impact model for the program, and advanced the development of a model to balance a renewable-based generation portfolio with projected load demand in the county. The ultimate objective is to help achieve Humboldt County's energy vision, which identifies near-term pilot projects, technology advancements, and policy updates as part of a long-term renewable energy development strategy, while also avoiding an expensive transmission upgrade.

The Benefits: This project will benefit the California electricity ratepayers by creating jobs and stimulating the Humboldt County economy. The results are expected to enable increased development of renewable energy resources in the county, particularly bioenergy (which already provides roughly one-third of the local electricity portfolio), wind, and small hydroelectricity. The community also benefits from deferred/avoided transmission upgrades and more reliable power for an isolated region. The results and lessons learned from this effort will be compiled in a RESCO planning workbook, which can be used by any other community aiming to develop its local renewable energy resources. Other products developed under this project that will also be helpful for other local governments in California include a *Policy and Regulatory Guide for Local Government Officials* and a RESCO outreach brochure.

Wind Turbines and Battery Storage Added to the Smart Grid Demonstration of Renewable Energy Secure Community at the Santa Rita Jail

The Issue: The Santa Rita Jail RESCO project is integrating its existing energy efficiency and generation systems with newly designed systems into a smart grid environment, with the goal of giving the jail added energy independence and security. Existing systems included 1.2 MW of solar photovoltaics, a 1-MW fuel cell cogeneration system, a power conditioning system, and

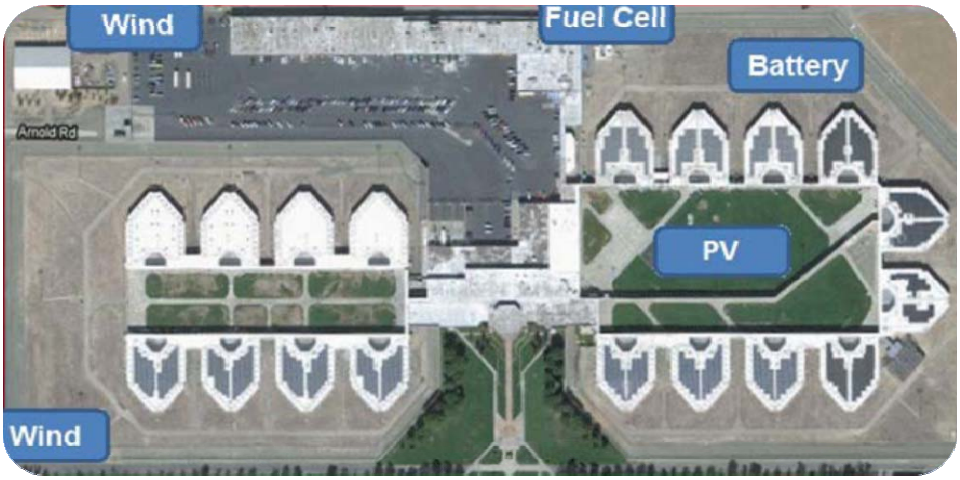
[20] http://www.nasdaq.com/aspx/stock-market-news-story.aspx?storyid=201112141224dowjonesdjonline000595&title=abb-invests-in-20million-in-ussolar-power-company.

a 2.4-kilovolt-ampere backup emergency generation system. With added energy systems the jail has the ability to disconnect ("island") from the utility grid when needed, without having to rely on the jail's onsite emergency generation backup system. This provides additional security to this high-demand, secure community, which houses roughly 3,700 inmates.

The Research: In 2011, researchers added five new small wind turbines with a capability of 11.5 kW, and a new 2 MW/4 MWh advanced energy storage lithium-ion battery system. Additionally, the researchers designed a new solar thermal system to generate up to 45,000 therms of hot water. This system was integrated with the existing cogeneration capabilities of the fuel cell that feeds the jail's existing centralized high-efficiency, low-nitrous oxide hot water boiler.

During the fall of 2011, the researchers installed and integrated the new energy storage battery system. This advancement successfully demonstrated the ability of the jail's integrated generation systems to disconnect from the utility when needed and to reconnect, with minimal energy load disruption.

Figure 13: Air Photo of Santa Rita Jail Energy Complex, December 2011



Source: Chevron/County of Alameda

The Benefits: The Santa Rita smart grid's plug-and-play compatibility characteristics make the integration of the new battery system with the existing power conditioning system possible so electricity demand during summer peak is decreased to zero. This allows the jail the potential to export energy and to reduce congestion and reliability on the local distribution grid, with up to a 15 percent reduction on the feeder circuit during summer peak load. The jail's existing energy efficiency measures remain in place, and this project provides continuing benefits toward reducing Alameda County's overall energy costs and resolving energy independence and system reliability issues. This project's successful, cutting edge research and demonstration will likely benefit California by enabling future applications under the PIER-funded RESCO model.

Non-Contact Drilling Research Improves Geothermal Drilling Technology

The Issue: Geothermal energy generation relies on drilling boreholes for both exploration and production. Using conventional technology, these holes can be a major portion of total

production costs, with costs increasing exponentially as the depth increases. This drilling typically uses special bits that wear out and must be replaced periodically. Exploration wells can cost up to one-third that of production wells, and a number of exploration wells are usually needed to accurately characterize a geothermal resource and site a power plant. The high risk and cost for drilling have led to financing costs of up to 20 percent, making project funding very difficult to obtain. Future geothermal technology using enhanced geothermal systems could open up vast new areas of geothermal resources. However, access to these areas will require drilling to depths of 10,000 feet or more. At these depths, the cost of conventional drilling is more than 60 percent of total expenditures.

The Research: As a means to lessen drilling costs, this PIER project, in 2011, field tested a technology focused on a novel drilling method that does not use a bit and does not contact the rock in the drill hole. Instead, a jet of superheated steam is directed at the rock surface, which causes rock layers to flake off. This mimics the naturally occurring flaking-off process that occurs in rocks like granites found in the Sierra Nevada Mountains. With this new method of drilling, this natural process is sped up and applied to the rock in the well bore.

The Benefits: Specifications for the drilling system were based on successful laboratory drilling demonstrations in blocks of Sierra White granite. The development conducted under this project led to fabrication and assembly of a field-ready drilling system, which is being tested in the Sierra foothills. This testing has confirmed the basic performance of the system design and led to ongoing system refinements. Research has indicated the potential for more than triple the increased rate of penetration when compared to current drilling technologies, which is expected to lead to significantly lowered costs for drilling geothermal wells. In the long term, it is also expected to result in cost-effective drilling for production wells for enhanced geothermal systems, which will increase power plant siting opportunities, as resources will be available in more locations, including areas close to existing electric transmission corridors. This should lead to an increased amount and percentage of geothermal energy in California – a low cost, base load renewable resource. California geothermal plants typically generate several tens of MW of efficient power for the state's residents. Each MW of geothermal power developed in California creates an estimated four construction jobs and 1.7 operation and maintenance jobs. A recent study indicated that geothermal power development has the potential to create 60,260 jobs in the state by 2017. [21]

[21] Source: Heavner, Brad and Bernadette Del Chiaro (July 2003). *Renewable Energy and Jobs: Employment Impacts of Developing Markets for Renewables in California*. Environment California Research and Policy Center. http://www.policyarchive.org/handle/10207/bitstreams/5474.pdf.

Using Battery Storage to Firm/Stabilize Wind-Generated Energy

The Issue: Wind energy output is often variable and unpredictable, resulting in grid stability issues. Large energy storage systems provide significant value in numerous ways, primarily electricity transmission support, frequency regulation, and firming up renewable availability. To capture the value they represent, much lower cost energy storage technology is required. A variety of energy storage solutions either exist or are emerging in the marketplace. Each has advantages and disadvantages from a capital and operating cost, reliability, and functionality perspective. Building on the U.S. Department of Energy (DOE) efforts, the Energy Commission is implementing programs to develop and bring to market cost-effective energy storage systems. Systems of particular interest are those that have the flexibility to capture revenue streams from multiple applications.

Figure 14: Energy Storage in Modesto, California

Source: Primus Power Corporation

The Research: This project is developing and demonstrating a 25 MW/75 MWh zinc-halogen (chlorine/bromine) flow battery storage system at a utility location for a wind firming application. The research team is working with a California utility to address its need for wind firming as it implements a program to fulfill the state's 33 percent renewables goal. The company began manufacturing and testing in 2011, and the system is scheduled to be installed early in 2013. This energy storage system is scheduled to replace a planned 25 MW fossil fuel plant, which would normally be required to compensate for the variable nature of wind energy.

The Benefits: Benefits include demonstrating the direct value of using clean energy solutions as alternatives to classic fossil generation systems. Once commissioned, this system will represent one of the largest operational battery energy storage systems on the California grid, providing critical information on performance, cost, and reliability of these types of large, utility-scale energy storage solutions. The information gained from this demonstration project will be directly relevant to applying similar systems throughout California and the nation. The specific business case information on how energy storage can be used to help firm the intermittent generation of renewable systems can help policy makers in California determine the proper mixture on the grid of renewable energy, energy storage, and other technologies that provide grid stability solutions.

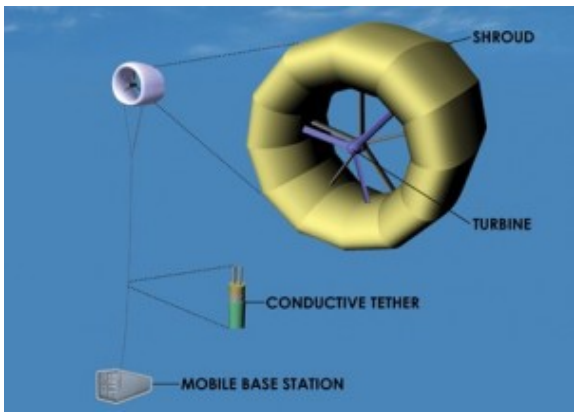
Energy Innovations Small Grant Program

In addition to large-scale demonstration projects, the PIER Program manages an Energy Innovations Small Grant (EISG) Program that awards grants not to exceed $95,000 to assess and evaluate new and innovative concepts and ideas. The next two projects, initiated in 2011, represent two promising EISG Program grants that are addressing the need to generate renewable energy that can be cost-effective and reliable.

Airborne Wind Turbines Reduce Average Cost of Offshore Wind Energy

The Issue: To date, high costs of establishing an offshore wind generation systems in deep water can result in very high system costs. Installing a platform that is both strong enough to withstand the high offshore winds and stabilized by being mounted on the ocean floor has limited the growth of renewable offshore wind generation. Deep-water, offshore wind energy that is cost-competitive with fossil fuel power is possible by developing an effective, practical system for harnessing high ocean winds.

Figure 15: Passively Stable Shroud for Airborne Wind Turbine



Source: Adam Rein, Altaeros Energies

The Research: This EISG project investigates the feasibility of using a helium-filled shroud, with no active control surfaces, to passively align an airborne wind turbine with the changing wind direction allowing the system to capture the maximum amount of renewable wind energy. An airborne wind turbine (AWT) was developed that has the potential to drastically reduce the average cost of offshore wind by an estimated 60 percent. This substantial cost reduction will bring this cost in line with the cost of onshore wind and other fossil fuel power sources. The AWT can operate at any water depth, making it ideally suited for deployment off California's coast where there is significant deep water. Additionally, it does not require a ground-collected platform normally required by offshore wind systems.

The Benefits: The AWT can benefit California ratepayers in three ways. First, it offers a novel approach to tapping California's rich offshore wind resources that are currently unavailable due to the deep water depth. Second, the AWT can help bring offshore wind onto the grid at a comparable average cost to natural gas, limiting the need to raise retail energy prices through rate hikes or surcharges to meet California's renewable energy portfolio targets. Finally, the high capacity factor of the AWT can reduce the load balancing required to support new renewable energy sources.

Energy Harvesting From Ocean Currents

The Issue: Energy from ocean currents is a new renewable technology that has the potential to meet a significant proportion of California's energy demands. The technology being evaluated in this project is assessing the ability to capture and harness the energy from the ocean currents and convert that energy into a renewable generation source. Like the previous example of the AWT, this technology can provide California an entirely new source of renewable energy that can potentially be cost effectively generated and replace fossil fuel generation systems.

The Research: This project, initiated in 2011, will investigate the theory that a new large-scale piezoelectric (directly converting pressure into electricity) technology based energy collection system can efficiently and economically generate power from renewable untapped ocean currents near the coast of California's outer continental shelf. The main outer continental shelf

currents are near California's coastline. The proximity of these currents to major population centers and the relatively constant flow make these currents ideal potential energy sources. The proposed piezoelectric generator system is based on the use of long thin beams or strips of piezoelectric polymer submerged under water in the ocean currents and capture the energy in the movements and convert that mechanical energy into electrical energy. The research provides performance, cost, and reliability assessments to allow business case details to be developed.

The Benefits: Energy extraction from ocean currents is still at an early stage of development, and significant work is needed to determine the viability of these resources for large-scale energy generation. As California transitions to more and more renewable generation, diverse sources of this energy provide the grid a more stable operating environment. Successful implementation of this technology can bring to California an entirely new renewable energy source.

Advanced Generation Research

Advanced generation research focuses on distributed generation (DG) and CHP technologies. This research subarea supports the technology development for electricity generation from renewable resources and other alternative fuels, with results that cut across the energy efficiency and energy infrastructure research programs. Primary past research initiatives have been devoted to increasing efficiency and reducing emissions while addressing the reliability, affordability, maintainability, and durability of power generation systems. A number of technologies have been commercialized (or are in the commercialization process) that demonstrate increased efficiencies and lower emissions than proposed regulations in the state. In 2011, research on advanced generation technologies was focused on:

- Developing advanced ultra-clean and highly efficient advanced power generation technologies such as fuel cells, gas turbines, and reciprocating engines for cost-effective and reliable cogeneration and CHP applications in California.
- Developing packaged CHP systems that are fuel-flexible, smart-grid ready, and easy to deploy and integrate with residential, commercial, and industrial buildings and operations.

Developing Combined Heat and Power Technology to Meet Air Quality Standards

The Issue: Reciprocating engines are key to cost-effectively addressing most of the state's CHP potential and are expected to remain the prime mover of choice for most CHP applications in California through 2020. Current engine emission control technology for stationary engines is lagging and is unable to meet the air quality regulatory requirements of the California Air Resources Board (ARB) for DG.

The Research: This project addresses the issue by funding the development, demonstration, and commercialization of an ultra-low emission engine control technology, which is packaged as an up-fit conversion kit for stationary natural gas engines. The project evaluated and tested sensor technologies for monitoring emission performance and accommodating pipeline natural gas and liquefied natural gas. It also developed a robust catalyst specification for effective reduction of pollutants and devised a software and air-fuel ratio control strategy for fast response and precise management of combustion and exhaust after-treatment processes of the engine. In 2011, the project commenced the field tests at Fontana Wood Preserving in Fontana, California, where it demonstrated that a 400-kW stoichiometric-operated, natural gas-fueled, reciprocating engine can maintain exhaust emissions levels below ARB's 2007 DG emission standards for extended periods of operating hours.

Figure 16: Engine Field Test of Ultra-Low Emissions System at Fontana Wood Preserving

Source: Southern California Gas Company

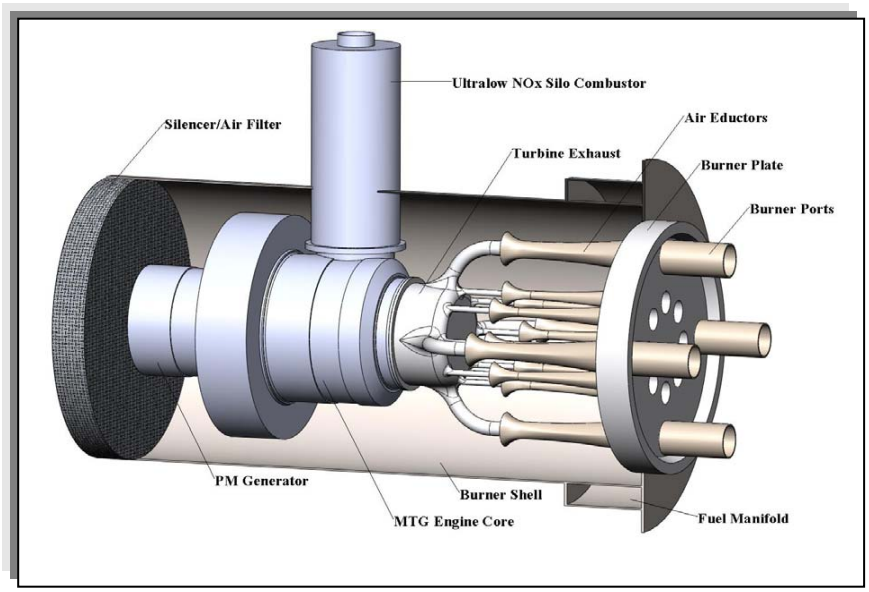
The Benefits: Project results will provide a number of tangible benefits including energy user cost savings, improved reliability of service, energy efficiency, reduced fuel consumption, reduction of GHG, increased power capacity, and improved grid resiliency. The DG and stationary natural gas engine CHP market now has the technology that can exceed and maintain continuous compliance with stringent emission regulations, such as the ARB 2007 and South Coast Air Quality Management District's emission standards for DG and CHP applications. The technology also provides affordable engine conversion kits for engines between 200 to 800 kW, which previously lacked a low-cost solution. Industries that have high heat load and can generate electricity using CHP now have the option to do so and still meet tight emission requirements. This makes industries, such as manufacturing, lumber, and food processing industries, more cost-competitive.

New, Efficient, Low-Emission Technology for Commercial Firetube Boilers

The Issue: The practice of retrofitting microturbine generators (MTGs) to commercial-scale firetube boilers in CHP applications has a large potential to increase energy efficiency. Current approaches employ MTGs with integrated recuperators (that is, system components that allow the use of a portion of the turbine waste heat to reduce the turbine combustor fuel consumption) and may also employ supplemental firing on the turbine exhaust side to improve boiler efficiency. However, the recuperated MTG approaches do not generally offer favorable payback to potential customers due to high MTG cost and recuperator durability problems. These approaches also lead to lower CHP efficiencies at a reduced load and have difficulty meeting stringent California emissions requirements.

The Research: To address these challenges, the project is developing and demonstrating the concept of boiler burner energy system technology (BBEST). In 2011, the project completed the system design and acquired necessary components to implement BBEST, which will employ a simple-cycle (unrecuperated) MTG in conjunction with an ultra-low nitrogen oxide (NOx) boiler burner integrated to a commercial-scale firetube boiler at a test facility in Sunnyvale, California. Upon completion of the BBEST performance evaluation, the packaged unit will be retrofitted to a large commercial firetube boiler at a hotel complex in Southern California.

Figure 17: Firetube BBEST System Illustration



Source: Altex Technologies Corporation

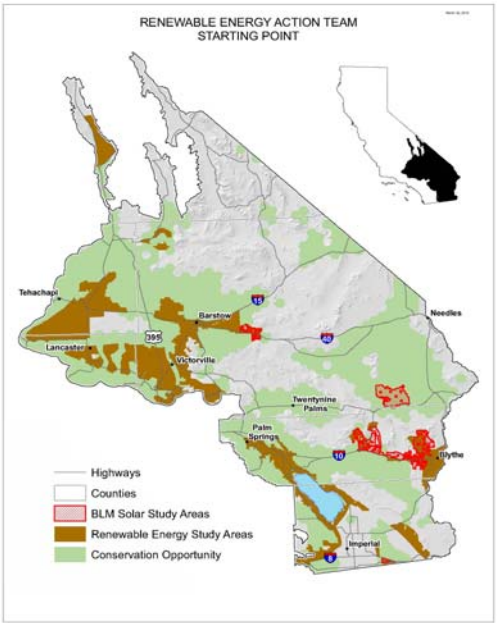
The Benefits: The simple-cycle MTG will be less expensive than an equivalent recuperated unit, with increased durability and reliability. Combined with the ultra-low NOx burner, the simple-cycle MTG could achieve up to 82 percent CHP efficiency while significantly reducing NOx emissions. The system will recoup installation costs through reduced energy usage in less than two years for a typical 100 kW electrical installation, with the expected cost of electricity at around $0.067/kWh. There are about 5000 potential sites[22], such as commercial boilers at office buildings, health care facilities and educational establishments, where this technology could be employed, for a total capacity of about 500 MW of electricity.

[22] The number was inferred from *Characterization of the U.S Industrial/Commercial Boiler Population* authored by Energy and Environment Analysis and submitted to Oak Ridge National Laboratory available at: http://www.cibo.org/pubs/industrialboilerpopulationanalysis.pdf.

Energy-Related Environmental Research Enables Renewables

A significant challenge in developing renewable energy projects is often the lack of data necessary to complete environmental permitting requirements. For example, in 2010 the Energy Commission approved nine concentrating solar developments representing 4,124 MW. Several of these projects received opposition in the administrative certification proceedings due to uncertainties related to the lack of appropriate scientific information to inform decision makers. Projects undertaken in 2011 are helping to promote Governor Brown's energy plan to add 20,000 MW of new renewable generating capacity by 2020, including 8,000 MW of large-scale renewable energy while minimizing environmental impacts.

Figure 18: Renewable Energy Action Team DRECP Starting Point Map Showing Renewable Energy Study Areas and Conservation Opportunity Areas



Source: Renewable Energy Action Team

Facilitating Renewable Energy Siting in the California Desert

The Issue: Utility-scale renewable energy facilities can have large land requirements, and those sited or proposed in desert areas can impact water supplies, ecosystems, and species that are of concern. The Renewable Energy Action Team, consisting of the Energy Commission, California Department of Fish and Game (DFG), U.S. Fish and Wildlife Service, and Bureau of Land Management (BLM), continues to develop the Desert Renewable Energy Conservation Plan (DRECP), which will guide renewable energy siting and conservation in the Mojave Desert and Colorado Desert of California.

The Research: To advance the DRECP and aid environmental review and permitting, the Energy Commission continues to expand its desert research program. As of 2011, PIER initiated seven desert projects in coordination with DFG and the Energy Commission's Siting, Transmission, and Environmental Protection (STEP) Division. Some of these are highlighted.

A Framework for Analyzing Cumulative Biological Impacts for Solar Energy Projects in the California Desert

The *Recommendations of Independent Science Advisors for the California Desert Renewable Energy Conservation Plan* (October 2010[23]) encourages several principles for siting and designing renewable energy developments. The first of these is to maximize the use of already disturbed lands. Researchers at the University of California at Santa Barbara have completed and shared with DRECP agencies and stakeholders the results of their "low-risk" desert modeling, which

[23] http://www.energy.ca.gov/2010publications/DRECP-1000-2010-008/DRECP-1000-2010-008-F.PDF.

uses the logic that highly degraded sites near infrastructure would have the least potential value for biodiversity conservation. This initial product, "Mapping compatibility to minimize biodiversity impacts of solar energy development in the California Deserts" is a multicriteria spatial model that identifies the relative level of compatibility of solar energy development and biodiversity conservation in California. Maps are accessible via a Web application developed and hosted by the Mojave Desert Ecosystem Program and through Google Earth, and a white paper describes the modeling. DRECP agencies are using this data from the PIER project "Cumulative Biological Impacts Framework for Solar Energy Projects in the California Desert" to make decisions in the ongoing planning process. Further collaboration is planned for ongoing use of this project's research results as they become available.

Decision Support System to Improve Mitigation and Facilitate Siting Renewable Energy

Protecting existing populations and habitat for the federally and state-listed desert tortoise, while implementing recovery actions to improve habitat quality, is a high priority as the state evaluates the potential development of solar resources in the desert. The lack of understanding of desert tortoise population effects has introduced considerable uncertainty and issues in the siting of multiple renewable energy developments and is the impetus for challenges to the Energy Commission's siting projects. In the project "Desert Tortoise Spatial Decision Support System," the University of Redlands and U.S. Fish and Wildlife Service are developing a Web-based modeling tool that quantifies the impacts of threats to desert tortoise populations from large-scale solar energy development and identifies and prioritizes recovery actions that are most likely to ameliorate those threats. Although the final tool will not be complete until 2013, the STEP Division is already using the researchers' calculations from a beta version to evaluate the effectiveness of desert tortoise mitigation measures for a recently permitted solar energy development. The researchers produced a report estimating the increase in risk to the desert tortoise resulting from modeled implementation of the solar project and the decrease in risk resulting from modeled implementation of mitigation and management actions by the Energy Commission and BLM. This PIER-funded report is assisting the Energy Commission and BLM in their ongoing consideration of how to address desert tortoise impacts.

Figure 19: The Desert Tortoise is a State and Federally Listed Species in Need of Targeted Conservation Efforts

Source: U.S. Geological Survey

Optimized Data to Enhance Renewable Energy Planning in California Deserts

Currently, the habitat distributions of many rare California desert plants are poorly understood and not well-documented. This data gap has hampered impact analyses and mitigation efforts related to renewable energy permitting. Therefore, improved distribution and habitat data collection, modeling, and field testing of models are required. These activities will help identify habitat areas beyond those places where rare plants are currently known to exist, guide rare plant habitat preservation decisions, and improve environmental analyses related to renewable energy development. In 2011 the UC Davis and UC Berkeley collaborative project "Mapping Habitat Distributions of Desert Rare Plants From Optimized Data" georeferenced and digitized collection data from 6,563 specimens of rare desert plants. This location and habitat data will enhance desert planning and environmental analyses and is now available to researchers, consultants, desert renewable energy stakeholders, and agencies online at the California Consortium of Herbaria, a gateway to information from plant collections at 19 California universities and botanical gardens, and at the California Natural Diversity Database, DFG's statewide data repository for geographic data on rare and endangered plants and animals. Additionally, this PIER project was featured in a local radio piece on solar energy.

Figure 20: Mojave Desert Wildflowers in California's Mojave National Preserve

Source: United States National Park Service

The Benefits: The goal of the desert research program is to remove barriers and delays in the siting of renewable energy in the desert. It will benefit the state and ratepayers by advancing the state's RPS goal and facilitating the completion of the DRECP, which will help ensure that the desert's renewable energy projects can provide clean energy and jobs to benefit California's ratepayers while helping to protect the state's fragile desert ecosystems. The projects above address critical data gaps, which hinder biological impact assessment and mitigation and can lead to costly delays in environmental permitting. They also provide data and planning tools to help overcome obstacles in the regulatory planning process. Even though this research program is only in the beginning stages, results from three of the projects are already being used by DRECP agencies and stakeholders to advise current environmental planning, permitting, and analysis. Results from this research program will be useful to agencies, researchers, and developers in siting and conservation planning, impact analyses, and mitigation, as well as in designing renewable energy facilities resulting in fewer environmental impacts.

Energy Infrastructure Research

To fully realize all the benefits of the PIER research and demonstrations in energy efficiency, renewable generation, and other areas, the critical link to the energy infrastructure is also being addressed to ensure the entire system operates effectively. The Energy Infrastructure Program area of PIER includes research advancements in transmission and distribution, smart grid, transportation energy, and environmental areas related to energy infrastructure. The state's goals to reduce fossil fuel use by increasing the deployment of alternative energy sources and gas-alternative vehicles are dictated to a large degree by the need to ensure energy independence and to combat the harmful effects of GHG emissions. Meeting these goals, however, carries an array of implications to energy reliability and costs, including an aging energy infrastructure that was not designed to handle high levels of localized energy production from DG, increased use from electrification of vehicles, and sporadic generation from intermittent availability of distributed renewable sources. The implementation of the smart grid is bringing together all these diverse areas into one comprehensive and optimized grid system. The growing demand for petroleum fuels for transportation will require significant investments in electric vehicle designs and alternatives to the state's petroleum infrastructure.

In addition to costs and reliability implications, energy generation, transmission, and use can impose significant demands on the state's limited water resources and contribute to unhealthy air quality conditions, while climate change can result in both greater energy demand and threats to existing vulnerable energy infrastructure.

Research completed in the Energy Infrastructure Program involves a wider spectrum of research priorities and challenges than the previous two research areas. The research is focused on demonstrating not only key products and elements of the energy infrastructure, but the successful and cost-effective integration of all these new and emerging technologies and solutions. The following examples provide a sample of the key energy infrastructure projects that completed substantial advancements in the last year.

"PIER's research program has resulted in the California ISO installing the most advanced synchrophasor application in the country relative to phase angle detection and oscillation detection. This is the most significant improvement in control room technology in my career."

Jim McIntosh, Director of Grid Operations, California ISO

Reliability Through Technology: Synchrophasors

The Issue: Increasing amounts of fluctuating, and often remotely located, renewable electricity pose a challenge to power grid reliability. Synchrophasors are a completely new method of electrical wave measurements, taken at two or more places on the grid to determine stability. To prevent costly electricity grid outages and to enable reliable integration of renewable energy sources, development and demonstration of synchrophasor technology applications are needed. Synchrophasor applications can be used to monitor grid power and present information to grid operators so they can take corrective actions to avoid blackouts or grid failures.

The Research: Over the years, PIER funded projects to develop a synchrophasor technology that monitors transmission grid operations. In 2011, a comprehensive assessment of the benefits of 15 years of synchrophasor research was completed to summarize and quantify economic and reliability benefits.

Energy Commission investment of $11 million in synchrophasor research alone will save ratepayers $210 million to $360 million in reliability benefits and $90 million in economic benefits.

The Benefits: Synchrophasors are estimated to lower the cost of electricity and use renewable resources more efficiently. The general benefits of PIER synchrophasor RD&D investments include decreased electricity costs, avoided outage costs, and improved monitoring of the status of the electric grid (to increase reliability). Other benefits include automated feedback and system correction as well as increased transmission capacity and successful integration of renewable energy sources.

Specifically, by 2020, the Energy Commission's $11 million investment in synchrophasor research and applications will save Californians an estimated $210 million in reliability benefits, plus $90 million annually in economic benefits, with the potential for more depending on policy decisions and research outcomes.

Turning a California University Campus Into a Premier Microgrid Technology Demonstration Platform

The Issue: Microgrids are a significant growth area for California's workforce-intensive employers like the industrial and commercial sectors, universities, and the military. Remote energy users also benefit from microgrid technology. Microgrids are infrastructure systems that are managed both as an independent grid system, as well as an integral part of the entire utility grid system. A microgrid represents an infrastructure model where the local operator can achieve energy independence and environmental sustainability by using emerging distributed energy resources and at the same time be connected to the state utility grid for other critical services. By operating as a microgrid, the facility can manage a variety of energy resources as an integrated system, expand the amount of renewable energy in the system, accept and implement new and creative energy efficiency measures, and provide demand response and other time-critical services to the larger utility grid. Research is needed to determine the extent by which microgrids enhance the efficiency and optimization of the local distribution grids and the California transmission system as a whole and to do this at a reasonable cost and high reliability.

The Research: The University of California, San Diego, (UCSD) has integrated a diversity of distributed energy resources onto its microgrid by leveraging four PIER-sponsored projects: Renewable Energy Secure Communities (RESCO), Mitigating Measures of High Solar Penetration, California Solar Collaborative, and Solar Forecasting and Energy Storage. As a result, most experts in the industry consider UCSD one of the premier microgrid technology demonstration systems in the field. UCSD has demonstrated a superior ability to leverage PIER funds as they were successful in obtaining additional project cofunding through San Diego Gas

& Electric (SDG&E), DOE, the U.S. Treasury's Clean Renewable Energy Bonds, CPUC's Self-Generation Incentive Program, California Solar Initiative, and the Statewide Energy Partnership. These projects made possible the operation of a pioneering 2.8 MW-fuel cell-using direct biogas from the local wastewater treatment plant, 2 MW of photovoltaics, two concentrating PV systems, and a 30 kW/30 kWh PV fully integrated storage system, all of which operate in seamless conjunction with an Environmental Protection Agency Star-Awarded 27-MW CHP plant and a 4 million gallon thermal storage system. All these systems are operated together through an innovative master system controller that collects and analyzes more than 50,000 data points per second and then manages the system in real time based on the operation priorities predefined by the university.

Figure 21: Microgrid Technology Demonstration System Complex, UC San Diego

Source: University of California, San Diego

The Benefits: In 2011, *Forbes* reported that UCSD represented a precursor of the smart grid, and because this microgrid is on a state university campus, the university has openly shared its lessons learned and operational successes with others throughout the industry. The UCSD microgrid continually demonstrates the value of integrating a wide range of diverse energy generation resources to meet the needs of critical customer load. This microgrid provides insight into how the future California smart grid can operate with higher penetrations of renewables, more distributed resources, and higher levels of energy efficiency (including demand response). For example, UCSD reduced imports from 11 MW to 2 MW (an 80 percent reduction) within a two-hour period without impacting any critical loads and now saves more than $800,000 per month by generating over 90 percent of its electricity demand and 95 percent of its heating and cooling requirements for its 13 million square feet of buildings. Using a "lab to market" strategy through public-private partnerships, UCSD has demonstrated two generations of concentrating PV systems. UCSD has been the launching pad to bring new renewable technology manufacturing capability into California. In December 2011, the CPUC approved a 305-MW contract between Soitec and SDG&E. This allowed the approval to construct a new Soitec manufacturing facility in San Diego that will create 450 new direct high-tech jobs and 1,000 indirect jobs in California. UCSD has also promoted other highly successful

technology transfer activities at other institutions by hosting the DOE's Microgrid Planning Workshop and the DOE-CPUC's Solar Forecasting and PV Integration Workshop.

The Future of Energy Storage in California

The Issue: Energy storage technology is considered one of the most critical new and emerging technologies to address the intermittent generation element of renewable technologies in California, and the nation has placed a high priority on the development, demonstration, and commercialization of energy storage technologies. Assembly Bill 2514 (Skinner, Chapter 469, Statutes of 2010) requires the CPUC to determine appropriate targets, if any, for privately owned electric utilities to procure viable and cost-effective energy storage systems. AB 2514 also recognizes that, despite many benefits of energy storage, there are significant barriers to obtaining the benefits of energy storage systems. These barriers include inadequate evaluation of the value of energy storage for integration of renewable energy resources, lack of recognition of technological and marketplace advancements, and inadequate statutory and regulatory support.

Understanding the performance, benefits, and costs of using energy storage technologies is a critical part of meeting the state's future renewable energy goals. To fully understand the capabilities and solutions provided by energy storage, field demonstrations of actual systems in the proposed application areas are a key step to progressing to the grid of the future. The American Recovery and Reinvestment Act (ARRA) funded more energy storage demonstrations both nationally and in California than have ever been funded at one time in history. The PIER Program provided match funding for many of these ARRA projects, and in 2011, most of these efforts began preparing for their field demonstrations that will occur in 2012 and 2013.

Figure 22: Lithium-Ion Hybrid Ancillary Power Unit by A123 Systems

Source: A123 Systems

The Research: Recognizing the value of energy storage technologies for generation, transmission and distribution, and end-use applications, the Energy Commission is cofunding 10 energy storage projects developing and demonstrating energy storage technologies such as lithium-ion and flow batteries, compressed air, and flywheel in many different applications such as wind firming, distributed energy storage for grid reliability, ancillary and renewables integration services including grid frequency regulation, use of excess renewable generation, electric vehicle integration, and load shifting. The purpose of these demonstrations is to generate real-world information on the performance of and gain experience on various energy storage technologies and their applications on the

grid. For various ARRA-funded energy storage projects in California, the DOE provided $151.5 million in ARRA funds. The Energy Commission, through its PIER Program, is providing $7 million as cost-share funds for these projects. The recipients are contributing $477.5 million out of total cost of $635.46 million for these projects.

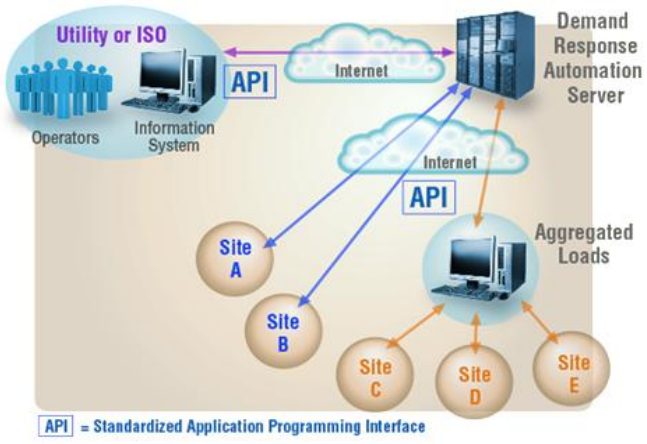
The Benefits: Energy storage research provides statewide benefits, such as reducing the cost of electricity, providing ancillary and renewable integration services, such as grid frequency regulation, load shifting, transmission congestion relief, increased reliability, capital deferral, shaving time off of peak demand, backup power, and increased reliability for industrial and commercial customers. It also offers the ability to integrate higher levels of renewables, while leveraging federal funds to create jobs and stimulate the economy, and reducing GHG emissions.

Renewable Energy and Stabilizing the Electric Grid

The Issue: Storage is versatile, yet expensive. However, electricity storage units can complement (or "firm") renewable resources more effectively than gas-fired plants. To meet the grid stability needs of the future as the state implements the 33 percent RPS, more energy storage and energy storage equivalent technologies are needed.

The Research: PIER funded a modeling effort by KEMA, Inc. that showed storage units charge and discharge instantly while gas-fired plants take some time to adjust, and some have to be kept running at a cost in money and emissions.[24] KEMA's modeling found that in the 33 percent renewables by 2020 scenario, 3000 MW to 4000 MW of firming power can effectively be supplied by fast-acting storage with a two-hour duration. KEMA also recommended research on the use of automated demand response (AutoDR) in place of storage for ramping and/or load following, and continuing development of the California ISO automated generation system controls algorithms that can implement this.[25] Preliminary estimates are that 1000 to 2000 MW of storage can be advantageously

Figure 23: Automated Demand Response



Source: Demand Response Research Center

[24] Masiello, R., Vu, K., Deng, L., Abrams, A., Corfee, K., Harrison, J., Hawkins, D., et al. (2010). *Research Evaluation of Wind Generation, Solar Generation, and Storage Impact on the California Grid* (CEC-500-2010-010). California Energy Commission, KEMA. Retrieved from http://www.energy.ca.gov/2010publications/CEC-500-2010-010/CEC-500-2010-010.PDF.

[25] Ibid., and personal communication with David Hawkins, Senior Principal Consultant at KEMA Consulting, January 2011.

provided by AutoDR. Based on current costs of the field implementation of AutoDR, it is conservatively estimated that the technology could provide similar services as energy storage at a potential cost of 10 percent or less of the expected costs of the energy storage.

The Benefits: To analyze the benefits of using OpenADR in place of storage, a detailed cost of storage analysis is required. PIER funded a market study of storage costs that was released in November 2011.[26] PIER's report summarized various costs of energy storage based on their potential uses, and came up with a very wide range based on project-specific factors such as operating cost and storage efficiency, wholesale energy prices, and the other potentially complementary value streams, such as avoided emissions, capacity values, and the cost to upgrade transmission and distribution. If OpenADR and energy storage can be managed as an integrated package, the state can expect to receive substantial cost savings when addressing the need for increase ancillary services in the future as the penetration of renewables expands.

Knowledge that storage can provide the necessary firming resource can promote further progress toward reducing its costs and perhaps avoid investments in gas-fired plants. An integrated package of energy storage and AutoDR can potentially reduce the overall cost to the state by 20 to 40 percent. If the grid of the future needs thousands of MW of new energy storage or energy storage equivalent systems, the savings of the integrated system could exceed $1 billion. Additionally, because AutoDR uses the existing infrastructure of buildings, industry, and appliances, these services can be provided without a large impact on grid infrastructure.

Expanding the Delivery of Renewable Energy With Intelligent Software Agent Technology

The Issue: Successful integration of renewable resources into the evolving California smart grid is essential to California's continued leadership in adopting renewable energy resources. The Energy Commission is investing in a diverse suite of technologies. One approach to addressing the needs of this integration is the development of intelligent software agents (software programs that operate independently to achieve a specific goal) to manage the interactions between the grid, renewable resources, and energy storage. Software agents allow the grid operator to develop and implement predetermined rules and decisions so these software agents can assess the conditions on the grid and respond immediately or notify an operator of an issue based on the decision authority they have been given. The use of these software agents has been demonstrated in many fields, but the criticality of energy management required that this new technology be demonstrated in the field in an appropriate application to prove the technology is safe, reliable, dependable, and responsive.

The Research: This project, completed in 2011, builds on previous PIER-funded research to develop intelligent software agents to manage the operation of distributed energy resources in response to dynamic electric rates. The project successfully developed and demonstrated that

[26] Intrator, J., Elkind, E., Abele, A., & Washom, B. (2011). 2020 Strategic Analysis of Energy Storage in California (CEC-500-2011-047). Public Interest Energy Research Program - California Energy Commission. Retrieved from http://www.energy.ca.gov/2011publications/CEC-500-2011-047/CEC-500-2011-047.pdf.

intelligent software agents can be used in a utility system to monitor and report status and when given the appropriate level of approval, make simple time-sensitive decisions. This project assessed the ability of the software agents to obtain data from the grid system when needed for the use of an energy storage system generated by intermittent wind resources and then provide guidance to that energy storage system on how to respond based on the needs of the grid.

The Benefits: This project demonstrated that applying intelligent software agent technology could expand the delivery of renewable energy through integration with storage technology and improved management of existing transmission and distribution facilities. The use of intelligent agents in the grid of the future provides part of the new distribution and grid automations capabilities expected to be included in the California smart grid of the future. The real-time feedback and management capabilities provided by these intelligent agents are expected to provide new information management options to grid system operators. Expanded demonstrations are planned in this area in the future.

Reducing the Effects of Wind on Dry-Cooled Power Plant Efficiency

The Issue: Due to concerns about energy demands on California's limited freshwater supplies, power plants are increasingly being built using dry-cooling systems. These systems use air-cooled condensers that directly reject the heat from steam condensation into the atmosphere and therefore have no water requirements. A modern gas-fired combined cycle power plant using a wet recirculating cooling system (conventional cooling towers) may consume more than three million gallons of freshwater a day; the vast majority is used for cooling (steam condensation). Use of air-cooled condensers, commonly referred to as dry cooling, however, may reduce power water consumption by up to 95 percent. Since air-cooled condensers reject heat directly to the atmosphere, however, high ambient heat and wind can reduce condenser performance and lead to reduced electricity generation.

Figure 24: Air-Cooled Condenser

Source: John Maulbetsch

The Research: To understand how wind affects air-cooled condenser performance and to identify ways to reduce these effects, this research collected information at a full-scale power plant using dry cooling. Results of this field testing, published in 2011, showed that the major wind effect on air-cooled condensers is a performance degradation of the large fans used to move air through the condenser. Reduced air movement through the condenser increases backpressure on the steam turbine, potentially reducing steam turbine performance up to 8 percent and, on occasion, more. A computer modeling analysis, using data from the field study, was also conducted to determine the air-flow patterns through

an air-cooled steam condenser under windy conditions. This analysis supported project findings from the field measurements. Finally, the study assessed existing wind mitigation measures at the power plant and recommended additional measures to reduce these fan effects.

The Benefits: A modern 500-MW combined cycle power plant may use 3 million or more gallons of water per day, mostly for cooling. By using dry cooling, this water demand can be reduced by up to 95 percent, but use of this cooling technology does reduce power plant efficiency. By advancing knowledge of wind effects on air-cooled condenser performance and ways to reduce plant efficiency losses, this project benefits California residents by promoting wider use of this water-conserving cooling technology and reducing energy demand on the state's limited water supplies, preserving precious water for higher value uses.

Estimating Risk to California Energy Infrastructure From Projected Climate Change

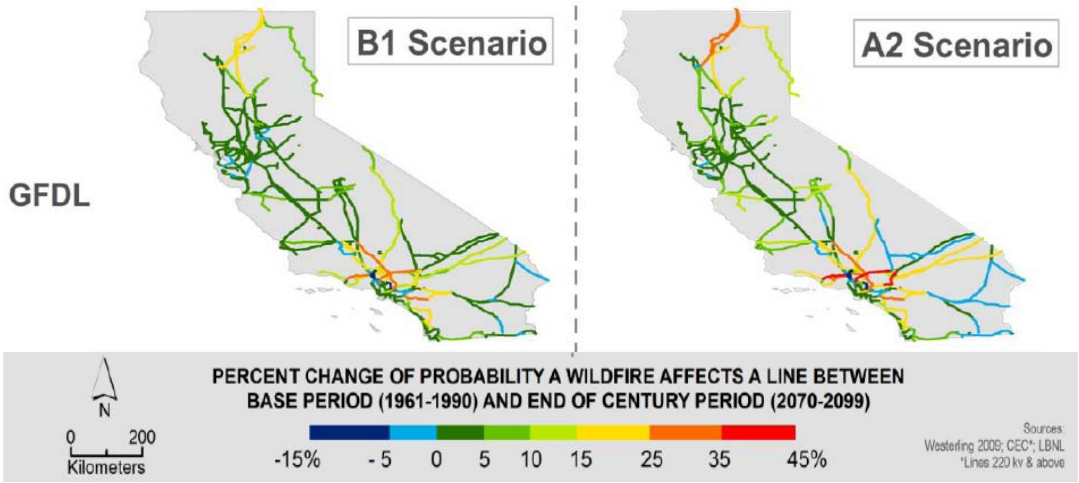
The Issue: Climate change is projected to result in significantly warmer temperatures in California over the 21st century, especially in the summer and in inland areas. Studies already show an increase in the frequency, magnitude, and duration of heat waves, with potentially harmful impacts to the energy system. In addition, prior PIER climate change research has shown that climate change will increase the frequency of large wildfires, substantially increase the risk of coastal flooding, and change precipitation regimes in California with impact on coastal power plants and hydroelectricity resource availability.

The Research: This project used the climate scenarios developed in prior PIER research to estimate the direct impacts of warming temperatures on California's electricity system, namely electricity generation, transmission, and demand. The results, published in 2011, indicated that at the end of the century, during August (one of the hottest months in California), rising temperatures will significantly impact electricity generation by decreasing natural gas power efficiency and subsequent plant generating capacity by 3 to 6 percent. In addition, electricity demand for almost all summer days is expected to exceed current "high peak" loads. The capacity of transmission lines would also decrease by about 7.5 percent.

Energy infrastructure will be affected in other ways, as well. Transmission line exposure to wildfires increases by as much as 40 percent, which would reduce the reliability of the overall electricity system. Also, up to 25 coastal power plants will see a substantial increase in the risk of flooding (or partial flooding) due to sea level rise.

The Benefits: While these projected impacts are significant, one of the main study findings is that the negative impacts from climate change described above can be avoided or reduced if climate change is taken into account when planning for California's electricity infrastructure. Implementing proactive measures, such as installing power plant intake chillers or dikes around costal power plants, will benefit California by helping to address diminished generation, transmission, and transformer capacity, as well as effects from increased fire risk and rising sea levels.

Figure 25: Percent Change of Probability That a Wildfire Could Affect a Transmission Line



Note: Areas in yellow to red reflect the greatest changes.

Source: California Energy Commission and Lawrence Berkeley National Laboratory

Climate Change Effects on California's Hydropower Resources

The Issue: In California, an average of 15 percent of electricity generation comes from hydropower. More important, hydropower is a substantial source of peak electricity generation during the very hot days and months of the year. The snowpack in California plays a central role in hydropower generation because it acts as a natural water reservoir. Climate change is altering California's precipitation regime in the Sierra Nevada Mountains and thus will affect the production of hydroelectricity in California. Therefore, climate change impacts on the state's total precipitation and snowpack have a direct affect on California's hydropower resources.

The Research: Prior PIER studies suggest that small air particles (aerosols) may be reducing precipitation levels by about 10 percent in the Sierra Nevada. This may cause a substantial loss of water, comparable to the capacity of several large manmade reservoirs. PIER, in collaboration with other state and federal agencies, is sponsoring a multiyear project, known as CalWater, to investigate the possible effects of aerosols on California's precipitation.

Figure 26: New Melones Dam

Source: http://www.energy.ca.gov/photos/get_pics.php?subject=Hydro&descriptors=New%20Melones%20Dam

In February 2011, a field campaign to collect and measure aerosol particles was implemented to probe impacts of airborne particles on the state's water and energy supply. During the field campaign a research airplane was used to collect aerosols where clouds are formed, confirming findings from a previous PIER study that dust plays a very important role in precipitation in California by converting precipitation in the form of rain to snow.

The Benefits: Hydropower contributes on average about 15 percent of the in-state generation in California and provides critical low-cost power in the hot months of the year experiencing peak electricity demand. As indicated above, aerosols may be reducing precipitation levels in the Sierra Nevada by about 10 percent, which will translate in a net reduction of critically needed hydropower generation. PIER research is essential to better forecast precipitating patterns, type (rain versus snow), and amounts to better forecast hydropower availability.

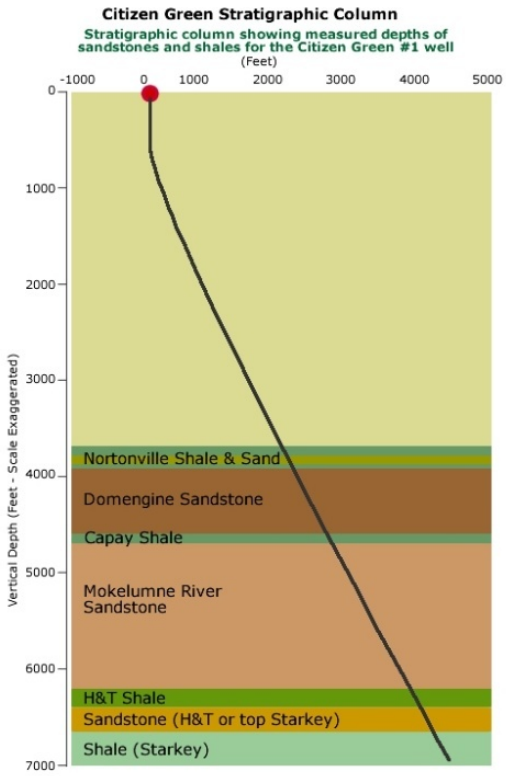
Carbon Capture and Storage at King Island, California

The Issue: The Energy Commission manages the West Coast Regional Carbon Sequestration Partnership (WESTCARB) for DOE. WESTCARB is one of seven national partnerships researching and demonstrating innovative methods of carbon capture, use, and storage. The WESTCARB partnership is laying the foundation for carbon capture and storage (CCS) development in the western region by assessing the CO_2 underground storage capabilities of the different regions in California. WESTCARB, a public-private research partnership funded by DOE and cofunded and managed by the Energy Commission, brings together more than 90 public agencies, private companies, and non-profits to identify and validate the best regional opportunities for addressing the many CCS needs of California and the entire western region of the nation.

Figure 27: Drilling Rig Running Wireline Logs

Source: Bevilacqua-Knight, Inc.

Figure 28: Well Trajectory Through Target Storage Formations



Source: Strata-Graphic, Inc.

The Research: In December 2011, WESTCARB completed drilling a well to evaluate the CO_2 storage potential of major rock formations in the southern Sacramento Basin, an area of high CCS potential in California. This WESTCARB research suggests that these formations may have the capacity to store hundreds of years' worth of the state's CO_2 point source emissions. Multiple core samples from recovered sandstone (the storage target) and shale (the sealing caprock) formations were recovered along with other data are being analyzed at Lawrence Berkeley National Laboratory and shared with two DOE Energy Frontier Research Centers and several universities to determine the physical, chemical, and biological characteristics of the formations. Tests on the cores will establish how CO_2 injection into these formations will alter these characteristics. The

core samples will be archived in the California Well Sample Repository at California State University, Bakersfield.

The Benefits: As California initiates a GHG cap-and-trade program in 2013, carbon capture and geologic storage may become an important compliance strategy. WESTCARB's research at the King Island site will help California's large CO_2 emitters better assess geologic storage options for meeting their GHG reduction obligations, as well as helping natural gas producers determine how CO_2 storage may extend the useful life of depleted reservoirs.

Energy-Related Transportation Research

Energy consumption for the transportation sector is responsible for almost 40 percent of all GHG emissions and more than 50 percent of all air pollution in California. To reduce the economic and environmental costs of transportation use in California, PIER's transportation research has focused on advancing the commercial viability of plug-in electric vehicles (PEVs) and reducing the state's total transportation energy demand through technological advancements in vehicle efficiency and through improved community planning that promotes greater use of mass transit, bicycling, and walking.

Reusing Lithium-Ion Vehicle Batteries to Cut Costs and Support the Grid

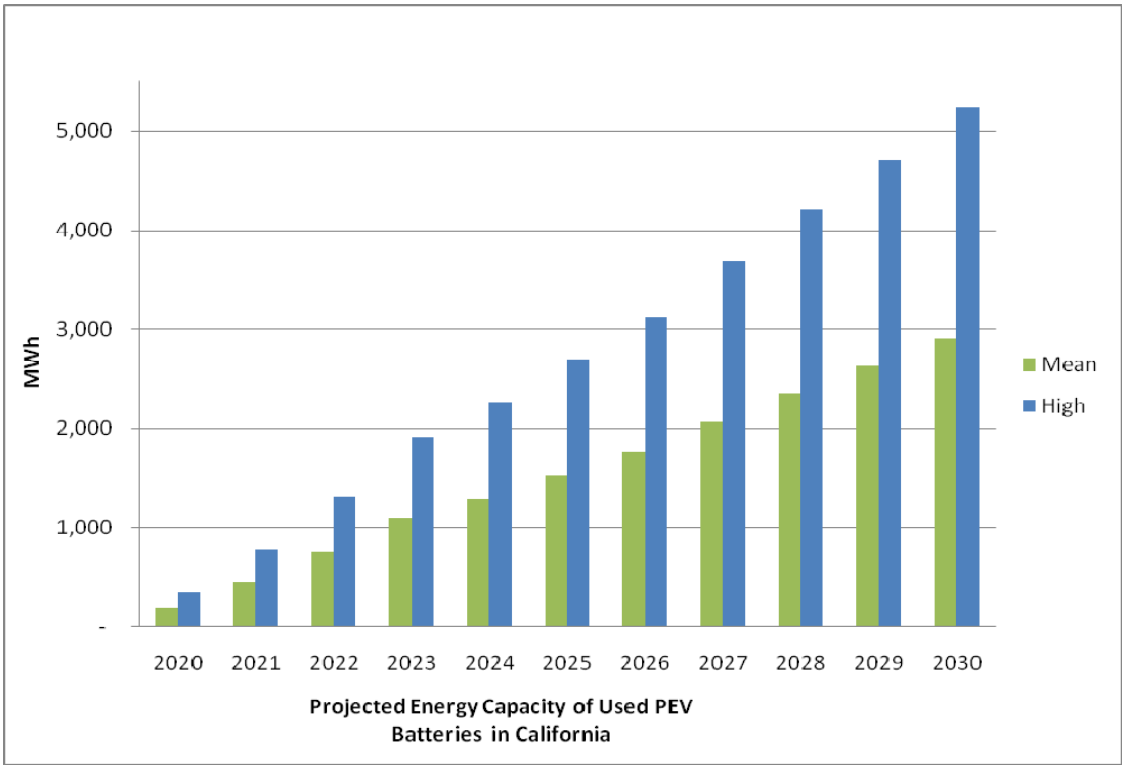
The Issue: The high cost of lithium-ion batteries is the primary barrier to the commercial success of plug-in electric vehicles. Battery costs alone can eclipse the cost of the rest of the car, if not the retail price of competing conventional vehicle alternatives. One potential strategy to reduce battery costs is to reuse the lithium-ion batteries – after they are no longer usable in the vehicle – in stationary energy storage devices. These devices might not only provide valuable services needed by existing statewide grid-support markets, but could provide customer-side-of-the-meter benefits, improve utility operation, help defer costly grid upgrades, and potentially support the profitability and penetration of intermittent renewable energy. The revenues generated from these "second-life" energy storage applications could potentially offset the high costs of the battery packs, lowering both the costs and risks to auto manufacturers and plug-in electric vehicle consumers. However, a number of technical issues need to be addressed before a viable market for second-life battery energy storage applications can develop.

The Research: The UC Davis Plug-in Hybrid Electric Vehicle Research Center – working collaboratively with the California Center for Sustainable Energy, San Diego Gas & Electric, Aerovironment, Inc., and the UC Berkeley Transportation Sustainability Research Center – conducted the first study on second-life storage applications for lithium-ion vehicle batteries. Advanced simulation tools were developed to evaluate the potential for second-life storage applications to supply ancillary services to the electrical grid. In 2011, results from the simulations determined that the most suitable and profitable storage applications for used vehicle batteries are "area regulation" and "load following." Testing to determine if used vehicle batteries could meet real-world requirements for "area regulation" and "load following" was performed on various battery packs and modules from different battery manufacturers and found that the majority of vehicle batteries performed exceptionally well in the simulated conditions.

The Benefits: An analysis of potential battery pack cost reductions from reusing lithium-ion vehicle batteries in stationary energy storage devices found that repurposing a 16 kWh battery pack, such as the one found in the Chevy Volt, for second-life storage applications could reduce battery lease payments by roughly 22 percent. Due to several uncertainties, the analysis found that battery lease payment reductions could range from 1 percent all the way up to 32 percent.

As a result of the Energy Commission's initial award, the National Renewable Energy Laboratory provided an additional $660,000 to this effort to conduct long-term field testing of second-life applications at the UC San Diego campus. This long-term testing, expected to begin in February 2012, will more fully advise key aspects of the potential second-life market for used plug-in electric vehicle battery packs.

Figure 29: Second-Life Applications for Lithium-Ion Vehicle Battery Packs



Source: California Center for Sustainable Energy

Addressing Barriers to Plug-In Electric Vehicles in California

The Issue: Recent studies have questioned the environmental benefits of PEVs. As PEVs are commercially deployed over the next decade, additional electricity generation from power plants will be needed to fuel these vehicles, shifting GHG emissions and air pollutants from the transportation sector to the electricity sector. As this shift occurs, questions remain as to: 1) whether the added GHG emissions and air pollutants from power plants negate the environmental benefits of PEVs, especially if PEV drivers recharge their vehicles during peak-demand hours; and 2) whether it is beneficial to differentiate electricity used for transportation fuel (electric fuel) from other electricity uses.

The Research: This project analyzed the net GHG emission and air pollutant impacts of PEV deployment in the nine-county San Francisco Bay Area in 2020. Results from the analysis in 2011 show that PEVs significantly reduce GHG emissions and air pollutants, even if charging occurs during peak-demand hours (uncontrolled) instead of off-peak demand hours (controlled).

The Benefits: This project estimates that the monetary benefits – from avoided human health impacts and avoided GHG emissions – are worth between $750 and $2500 per vehicle.

This project also assessed the benefits of differentiating electric fuel from electricity used for other purposes. These benefits include:

- Allowing Low Carbon Fuel Standard credits for PEVs to be properly allocated.
- Allowing utilities to track and treat electric fuel differently than other electric loads (for example, by booking investments and structuring rates differently).
- Helping ease the implementation of time-of-use rates to encourage off-peak charging.
- Allowing for the eventual taxation of electric fuel to make up for lost road-maintenance and other funds currently supplied by gasoline taxes.

CHAPTER 3: Conclusion and Next Steps

Conclusion

As a significant influence in the world's economic and energy future, California has the taken the leadership role of supporting aggressive policy goals and funding innovative energy projects that result in emerging technologies, standards, and strategies. To date, PIER has invested more than $800 million in RD&D funds, reaping benefits that far outweigh the costs. Nobel laureate Robert Solow estimates 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.[27] This means that for every dollar invested in RD&D, the return is $1.66. Additionally, PIER's proven ability to leverage private and federal funds has brought $11 for every $1 in public electricity funds invested in 2011.

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. In addition, the Energy Commission invests ratepayer funds in California, which helps create jobs and stimulate economic growth.

Over the last 14 years, the PIER Program has responded to evolving policy goals and market needs. The program initially focused on research involving individual components and has progressed to emphasize integration of multiple energy technologies to maximize synergies and benefits. As an example, there are now energy RD&D projects involving large-scale integration of energy efficiency, community-scale renewable energy, and consumer technologies, such as electric vehicles, interfacing with a smart grid that ensures reliability.

Next Steps

At the end of 2011, the mechanism under Public Utilities Code Section 399.8 for collecting PIER electricity funds, known as the Public Goods Charge (PGC) expired, and the Legislature did not reauthorize funding. Recognizing the importance and benefits of the program, Governor Brown requested the CPUC take action to ensure that programs like those supported by the PGC are reinstituted and to take into account the constructive ideas for program reform that were identified during the legislative process. On December 15, 2011, the CPUC authorized the Electric Program Investment Charge (EPIC) to collect funds for renewable and RD&D activities. In that decision, the CPUC decided the next phase of the CPUC proceeding would determine research activities, funding levels, administration, and governance.

Under the Energy Commission, public interest has been and remains the paramount guiding theme in the administration of RD&D using ratepayer funds to provide benefits to California's

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

citizens. Arguments have been made, and history shows, that moving the administration to a nonpublic entity would narrow the focus to private, market-driven profits. Publicly administered RD&D ensures transparent and accountable data and research results, a balanced portfolio, maximum leveraging of funds with private and other government entities, and direct accountability to the public, fund ratepayers, and the Legislature.

Given the importance of continued ratepayer funding for development and deployment of clean technologies in the energy sector and PIER's successful role as the administrator of these funds for the last 16 years, the Energy Commission is optimistic that the CPUC decision will designate the Energy Commission as future administrator of the EPIC funds.

In 2011, the PIER Program narrowed the scope of environmental (particularly climate change) and transportation research while still meeting current statutory requirements. New environmental and transportation projects must have a compelling and direct energy nexus. This has created a void in vital research for California. While this research has been instrumental to California in forming policy and providing mitigation and adaptation strategies to reduce impacts from energy-related climate change projections and vehicle emissions, other sources of funding will likely be necessary to continue such public interest research in the future.

In 2012, the Energy Commission's RD&D program will continue to encumber fiscal year 2011/2012 funds to address critical state energy policy goals and objectives, as established by the Governor and the Legislature and approved by the Advisory Board, to support research initiatives in the following areas:

- Developing and demonstrating energy efficiency technologies and advising building and appliance standards
- Demonstrating zero net energy buildings and energy-smart communities
- Increasing energy efficiency in major energy end-use sectors, including buildings, industrial, agricultural, and water sectors
- Incorporating automated demand response technologies into a statewide smart grid infrastructure
- Accelerating deployment of multiple renewable technologies and community-scale generation
- Addressing intermittency, integration, and interoperability of renewable energy sources
- Providing information necessary to aid permitting of energy facilities, protect energy infrastructure, and reduce GHG
- Advancing electric and natural gas vehicle technologies

APPENDIX A:
2011 Individual Electricity Research Projects

This table contains a summary of the electricity research projects initiated (that is, contracts executed and/or approved at an Energy Commission Business Meeting) during calendar year 2011. The projects listed below were funded entirely with electricity funds or have the majority of their funding from electricity funds. Also included are projects that were previously initiated but had formal amendments to encumber funds in 2011. A total of 111 electricity projects were initiated (or amended to add funds) in calendar year 2011.

Agreement #	Project #	Entity*	Project Title	Project Amount	Match Amount	Start Date**
500-01-043	5	The Regents of the University of California on behalf of the California Institute for Energy and Environment	Enabling Smart Grid and the Integration of Renewable Generation Technologies	$2,522,048	$0	6/29/2011
500-05-001	3	Lawrence Berkeley National Laboratory	Analysis of implementation activities impacting demand response as a system reliability resource for the CAISO.	$50,037	$0	9/1/2011
500-08-053	1	California Lighting Technology Center - UC Davis	Realizing Energy Efficient Lighting in California	$311,481	$155,000	3/23/2011
500-10-021	1	The Regents of the University of California, Santa Barbara (Bren School of Environmental Science & Management)	Cumulative Biological Impacts Framework for Solar Energy Projects in the California Desert	$383,787	$0	3/7/2011
500-10-022	1	Electric Power Research Institute (EPRI)	Using Advanced Power Electronics to Save Energy in Consumer Electronics and Motorized Appliances	$1,856,899	$500,000	4/1/2011

Agreement #	Project #	Entity*	Project Title	Project Amount	Match Amount	Start Date**
500-10-023	1	The Regents of the University of California on behalf of the California Institute for Energy and Environment	Smart Grid Research Development and Demonstration Assessment	$300,000	$0	6/20/2011
500-10-027	1	U.S. Geological Survey	Potential Habitat Modeling, Landscape Genetics and Habitat Connectivity for the Mohave Ground Squirrel	$223,755	$0	1/17/2011
500-10-028	1	The Regents of the University of California, Davis	Integrated Whole Building Energy Efficiency Retrofit Solutions for Untapped Markets	$1,995,032	$1,197,500	3/31/2011
500-10-030	1	The Regents of the University of California, Davis	Considering Climate Change in Hydropower Relicensing	$299,970	$0	2/28/2011
500-10-032	1	Institute of Transportation Studies - UC Davis	Water Demand and Impacts of Development of California's Alternative Transportation Fuels	$124,000	$0	3/28/2011
500-10-033	1	The Regents of the University of California on behalf of the Los Angeles Campus	Methodology to Develop a Comprehensive Tool for Evaluating and Analyzing Regional Energy Use and its Environmental and Socioeconomic Impacts for California's Regions	$1,000,000	$0	4/11/2011
500-10-034	1	Delta Diablo Sanitation District	Bay Area Biosolids to Energy	$999,924	$3,739,000	5/9/2011
500-10-035	1	UC Berkeley	Winter fog and energy demand in the Central Valley	$82,416	$0	6/29/2011
500-10-040	1	Advanced Power and Energy Program - UC Irvine	Energy, Air Quality, Water and Climate Change Co-Benefits of Renewable Generation and Fuels Roadmap	$127,955	$0	6/20/2011

Agreement #	Project #	Entity*	Project Title	Project Amount	Match Amount	Start Date**
500-10-041	1	Scripps Institution of Oceanography - UC San Diego	Meteorological and Hydrologic Models to Forecast Effects of Climate Change on Energy Demand and Hydropower Generation	$1,200,000	$0	6/30/2011
500-10-043	1	The Regents of the University of California, San Diego	Renewable Resource Management for Solar Insolation Forecasting, Observability of Microgrid Operations, Demonstrate Distributed Energy Storage Systems and Renewable Energy Charging of Electric Vehicles	$1,394,298	$439,644	6/20/2011
500-10-045	1	UC Santa Barbara	The Projected Effects of Climate Change Induced Changes in Vegetation on Future Hydrologic Energy Generation in California	$600,000	$0	6/30/2011
500-10-046	1	UC Berkeley	Enhancement to the Development of Forest Carbon Inventory and Monitoring Tools Using Remote Sensing	$400,000	$165,000	6/30/2011
500-10-047	1	UC Berkeley	Potential Energy Scenarios for California and Their Environmental Consequences	$900,000	$0	6/30/2011
500-10-048†	Multiple	California Institute for Energy and Environment	• Project 2: Advanced Combined Cooling Heat and Power for Building Efficiency • Project 3: Solar Thermal for Efficient Combined Cooling, Heat, and Power • Project 4: Improving Heating/Cooling Systems with Phase Change Materials • Project 5: Mini-Channel Technology to Improve Solar Water Heaters • Project 6: Wireless Measurement Tools for Energy-Efficient Indoor Environments • Project 7: Saving Energy in Buildings With Adaptive Lighting Systems	$3,923,590	$0	7/1/2011

Agreement #	Project #	Entity*	Project Title	Project Amount	Match Amount	Start Date**
			• Project 8: Saving Energy in Buildings With Adaptive Envelope Systems • Project 9: Improved HVAC Through Standards for Technician Instruments • Project 10: Improving HVAC Electric Motor Systems in Buildings • Project 11: Enabling Renewable Fuels Through Flexible Burners • Project 12: Gasification of Almond Shell Biomass for Natural Gas Replacement			
500-10-049	1	The Regents of the University of California on behalf of the California Institute for Energy and Environment	State Partnership for Energy Efficient Demonstrations	$2,515,918	$0	6/30/2011
500-10-051	1	Lawrence Livermore National Laboratory	Using High Speed Computing to Estimate the Amount of Energy Storage and Automated Demand Response Needed to Support California's RPS.	$1,750,000	$0	6/30/2011
500-10-052†	Multiple	Lawrence Berkeley National Laboratory	• Project 3: Simulation Models for Improved Water Heating Systems • Project 4: Improved Standards Through End-use Meter Development • Project 7: Efficient Electronics Through Measurement and Communication • Project 8: Innovative Air Cleaner for Improved Indoor Air Quality and Energy Savings • Project 9: Improved Audio-Video Efficiency Through Inter-Device Control	$1,845,000	$0	7/1/2011

Agreement #	Project #	Entity*	Project Title	Project Amount	Match Amount	Start Date**
500-10-054	1	California State University, Fresno Foundation	Methodology for Characterizing Desert Streams to Facilitate Permitting Solar Energy Projects	$297,948	$0	6/30/2011
500-10-056	1	Water Research Foundation	Advancing Process Optimization and Energy Efficiency in the Water Industry	$425,000	$425,000	6/30/2011
500-10-057	1	AWS Truepower, LLC	Application of a Solar Forecasting System to Utility Sized PV Plants on a Spectrum of Timescales	$442,136	$105,826	6/30/2011
500-10-058	1	Transportation Power, Inc.	Grid-Saver Fast Energy Storage Demonstration	$1,411,495	$520,004	6/30/2011
500-10-059	1	Clean Power Research	Demonstration and Validation of PV Output Variability Modeling	$450,000	$90,000	6/30/2011
500-10-060	1	EnerNex, LLC	Utility Scale Solar Forecasting, Analysis and Modeling	$450,000	$140,217	6/30/2011
500-10-061	1	Project Navigator, LTD	California Landfill-Based Solar Projects	$120,000	$40,000	6/30/2011
500-10-062	1	Satcon Technology Corporation	Grid-interactive photovoltaic system with DC-link battery storage integration	$1,972,211	$1,345,332	6/30/2011
500-10-063	1	Combined Power Cooperative (formerly Advanced Lab Group Cooperative)	Hyperlight Low-Cost Solar Thermal Technology	$1,000,000	$447,175	6/30/2011
500-10-065	1	UC Irvine	California Plug Load Research Center	$1,000,000	$0	7/1/2011
500-11-002	1	The Regents of the University of California	Pacific Region Combined Heat and Power Application/Education Center	$240,000	$0	9/12/2011
500-11-003	1	UC Irvine	Self-Audit of Wastewater Treatment Processes to Achieve Energy Optimization, Phase 2	$347,914	$117,500	9/1/2011
500-11-006	1	San Diego Gas & Electric Company	Determining Best Location for Energy Storage to Maximize Effectiveness with Residential Renewable Generator Clusters	$539,350	$0	11/7/2011
500-11-007	1	San Diego Gas & Electric Company	Electric Vehicle Charging Simulator for Distribution Grid Feeder Modeling	$680,000	$592,000	11/7/2011

Agreement #	Project #	Entity*	Project Title	Project Amount	Match Amount	Start Date**
500-11-009	1	The Regents of the University of California, Davis	Wind Ramp - Short Term Event Prediction Tool - Development and Implementation of an Analytical Wind Ramp Prediction Tool for the CAISO	$398,662	$109,364	12/15/2011
500-11-010	1	The Regents of the University of California, Davis	WindSENSE-Determining the Most Effective Equipment for the CAISO to Gather Wind Data for Forecasting	$646,661	$76,986	12/14/2011
500-98-014†	338	Altaeros Energies, Inc.	Passively Stable Shroud for Airborne Wind Turbine to Reduce Average Cost of Offshore Wind Energy	$93,160	$0	10/5/2011
500-98-014†	358	AOS Solar Inc.	Converting Waste CO2 to Methane and Energy	$95,000	$0	11/2/2011
500-98-014†	345	California State University, Northridge	Harvesting from Ocean Currents Using Piezoelectric Element	$49,999	$0	10/5/2011
500-98-014†	342	CHA Corporation	Microwave System for Hydrogen Production from Dairy Digester Biogas	$95,000	$0	10/5/2011
500-98-014†	357	Cool Earth Solar, Inc.	Portable Low Cost Meteorological Station for Solar Resource Measurement and Forecasting	$95,000	$0	11/2/2011
500-98-014†	341	Duke University	Hybrid Solar System for Stationary Electric Power Generation	$95,000	$0	10/5/2011
500-98-014†	350	Green Dot Inc.	Seamless Mechanized Charging Interface for EV/PHEV	$94,953	$0	10/5/2011
500-98-014†	359	Jasper Ridge LLC	High Performance Battery Exploiting Scaled Manufacturing Technology	$95,000	$0	11/2/2011
500-98-014†	335	Lighting Research Center - Rensselaer Polytechnic Institute	High-Efficiency LED-based Linear Flourescent Replacement Lamp	$95,000	$0	1/26/2011
500-98-014†	356	Makel Engineering, Inc.	Low Cost MEMS Biogas Fuel Quality Meter for Power Generation	$94,157	$0	11/2/2011
500-98-014†	333	Miami University - Ohio	Development of Flexible Die Sensitized Solar Cells	$94,931	$0	1/26/2011

Agreement #	Project #	Entity*	Project Title	Project Amount	Match Amount	Start Date**
500-98-014†	349	Mission Motor Company	Lightweight Onboard Charging Device for Electric Vehicles	$94,000	$0	10/5/2011
500-98-014†	351	Mogavero Notestine Associates	Development of High Density Housing around Integrated Agricultural Lands and Corresponding Transportation Energy Impacts	$50,000	$0	10/5/2011
500-98-014†	325	Momentum Dynamics Corporation	Wireless Electric Vehicle Recharging Systems	$95,000	$0	1/5/2011
500-98-014†	334	NanoRIS	Fabrication of Doped Nanowires for High-Temperature Thermoelectric Materials, Reducing Thermal and Electrical Loss	$94,780	$0	1/26/2011
500-98-014†	337	New Mexico State University	Stable Fully Distributed Multiagent Based Load Management Algorithm for Microgrids to Balance Microgrid's Distributed Resources and Loads	$49,991	$0	10/5/2011
500-98-014†	340	nLiten Energy Corporation	High-Efficiency Thin-film solar Cells on Nanostructured Substrates	$95,000	$0	10/5/2011
500-98-014†	332	San Diego State University	Flameless Combustion in Air-Cooled, Hybrid Solar Central Receivers	$94,940	$0	1/26/2011
500-98-014†	322	The Curators of the University of Missouri	Lower Cost and Higher Density PHEV Battery	$95,000	$0	1/5/2011
500-98-014†	Multiple	The Regents of the University of California on behalf of the Los Angeles Campus	• Project 323: Validated Multi-Scale Analysis Tool for Mechanical Response of Open-Cell Aluminum Foams • Project 327: Bonding of Metal-Plastic Composites for Lightweight, Fuel Efficient Vehicles	$139,919	$0	1/5/2011
500-98-014†	344	The Regents of the University of California, Irvine Campus	Monitoring and Feedback System for Improved Building End-Use Efficiency	$91,410	$0	10/5/2011

Agreement #	Project #	Entity*	Project Title	Project Amount	Match Amount	Start Date**
500-98-014†	343	The Regents of the University of California, San Diego	Tar Removal by Catalyzing Gasification bed Materials for Power Generation	$95,000	$0	10/5/2011
500-98-014†	339	UC Berkeley	Smart Wind Turbine: A New System for Improved Energy Yield	$49,560	$0	10/5/2011
500-98-014†	328	UC Davis	Smart Photovoltaic PHEV/EV Charging System Using Second-Life Lithium Batteries	$94,250	$0	1/5/2011
500-98-014†	352	UC Riverside	Reducing Mobile Air Conditioner Power Consumption in Hybrid Electric Vehicles	$94,948	$0	10/5/2011
500-98-014†	354	UC Santa Barbara	Autonomous Flexible Wings for High-Altitude Wind Energy Generation	$95,000	$0	11/2/2011
500-98-014†	348	University of Toledo, Ohio	Impacts of Plug-in Hybrid Electric vehicles on Distribution Network Reliability	$50,000	$0	10/5/2011
500-98-014†	321	XCell Power, LLC	Metal-Supported Solid Oxide Fuel Cells for APU Applications	$94,910	$0	1/5/2011
MRA-02-088	1	The Regents of the University of California on behalf of the California Institute for Energy and Environment	Strategic Analysis of Energy Storage Technology	$324,998	$0	2/1/2011
PIR-09-019	1	Potter Drilling, Inc.	Development of a Non-Contact Drilling Technology for Geothermal Wells	$380,000	$7,099,243	1/10/2011
PIR-10-004	1	Sacramento Municipal Utility District	SMUD's Smart Grid Pilot at Anatolia	$500,000	$4,300,971	6/30/2011
PIR-10-012	1	Washington University	Advanced Water Treatment Technologies for Onsite Water Reuse	$206,433	$0	6/24/2011
PIR-10-013	1	Lawrence Berkeley National Laboratory	Data Center Economizer Cooling with Tower Water	$200,000	$0	7/19/2011
PIR-10-014	1	Lawrence Berkeley National Laboratory	Demonstration of Intelligent Control for an Enterprise Datacenter	$400,000	$0	7/25/2011
PIR-10-020	1	PAX Scientific, Inc	High Efficiency Data Server Fans	$287,757	$96,188	3/1/2011

Agreement #	Project #	Entity*	Project Title	Project Amount	Match Amount	Start Date**
PIR-10-023	1	Utility Savings & Refund, LLC	Application of High Capacity Electric Energy Storage via Vanadium Redox Flow Batteries, in conjunction with Fuel Cells, to a Wastewater Treatment Facility	$400,000	$0	3/7/2011
PIR-10-029	1	Primus Power Corporation	Using Battery Storage to Firm/Stabilize Wind-Generated Energy	$1,000,000	$0	7/1/2011
PIR-10-034	1	Sacramento Municipal Utility District	SMUD's Smart Grid Proposal for FOA 58	$1,000,000	$307,591,845	6/1/2011
PIR-10-035	1	City of Anaheim	Anaheim Smart Grid Enhancement Project	$589,603	$11,499,500	6/30/2011
PIR-10-046	1	Fiscalini Farms Management, LLC	Fiscalini Farms Dairy Digester and CHP Project	$399,625	$544,150	3/8/2011
PIR-10-048	1	Redlands Institute, University of Redlands	Desert Tortoise Spatial Decision Support System	$350,000	$69,909	2/3/2011
PIR-10-049	1	Soladigm, Inc.	Low Cost Energy Saving Solid-State Smart Windows	$400,000	$5,379,237	2/15/2011
PIR-10-051	1	Portland Energy Conservation, Inc.	Curriculum for Commissioning Energy Efficient Buildings	$120,000	$1,478,027	1/3/2011
PIR-10-054	1	Stanford University	Large-Scale Energy Reduction through Sensors, Feedback & Information Technology	$500,000	$5,006,011	2/28/2011
PIR-10-055	1	Applied Materials, Inc.	Advanced Epi Tools for Gallium Nitride Light Emitting Diode (LED) Devices	$500,000	$7,594,369	4/18/2011
PIR-10-057	1	SeaMicro Incorporated	SeaMicro Volume Data Server Power Reduction Research and Development for Data Centers	$250,000	$19,740,000	3/1/2011
PIR-10-058	1	Edison Material Technology Center	Development of Very Dense Liquid Cooled Computing Platform	$250,000	$2,843,985	2/1/2011
PIR-10-059	1	Simbol, Inc.	Technologies for extracting valuable metals and compounds from geothermal fluids	$380,000	$6,280,682	6/30/2011

Agreement #	Project #	Entity*	Project Title	Project Amount	Match Amount	Start Date**
PIR-10-060	1	Calpine Corporation	Caldwell Ranch Geothermal Energy Reservoir Exploration and Confirmation Project	$410,000	$12,531,927	4/28/2011
PIR-10-061	1	The Regents of the University of California, Davis	UC Davis West Village Energy Initiative: ARRA Cost Share Funding	$500,000	$0	6/30/2011
PIR-10-062	1	Terralog Technologies	Characterization of Wilmington Graben for Large Scale CO2 Geologic Storage	$500,000	$11,774,766	5/14/2011
PIR-10-065	1	Amber Kinetics, Inc	Utility-Scale Flywheel Energy Storage Demonstration	$369,466	$9,633,549	9/1/2011
PIR-10-066	1	EnerVault Corporation	Flow Battery Solution to Smart Grid Renewable Energy Applications	$476,428	$9,052,139	9/1/2011
PIR-10-068	1	Electric Power Group	CAISO SynchroPhasor Technology Investment & Implementation	$999,743	$32,000,000	4/11/2011
PIR-10-069	1	City of Glendale	Glendale Water & Power Smart Metering and Demand Response - Marketing Public Benefits	$1,000,000	$50,302,105	6/1/2011
PIR-11-001	1	Seeo Inc.	Solid State Batteries for Grid-Scale Energy Storage	$600,000	$11,792,122	11/21/2011
PIR-11-002	1	Sacramento Municipal Utility District	Premium Power Distributed Energy Storage Systems Demonstration for National Grid and SMUD	$227,000	$5,417,123	12/15/2011

NOTES

***Entity note**: Research projects can occur at a number of sites in addition to the location of the awarded entity listed here. In several cases, the research entity disperses funds to a wide variety of research locations.

****Start date note**: This is the date the contract was signed and executed. In the few cases of contracts pending final signatures, the date listed is the Energy Commission Business Meeting approval date.

†**Note for the applicable projects**: In the three cases of agreements containing multiple projects, the encumbered amounts, which contribute to the 2011 total electricity research funds encumbered, differ from the project amounts reported here for the following reasons:

- These projects yield both electricity and natural gas benefits and therefore have funds from both accounts.
- In some cases such as the Energy Innovations Small Grant Program, which has been in existence since 1998, projects starting in 2011 can be funded with encumbered funds from earlier years.

Acronyms

AB Assembly Bill
ARB California Air Resources Board
ARRA American Recovery and Reinvestment Act
AutoDR automated demand response
AWT airborne wind turbine
BBEST boiler burner energy system technology
BLM Bureau of Land Management
California ISO California Independent System Operator
CCS carbon capture and storage
CHP combined heat and power
CO_2 carbon dioxide
CPU central processing unit
CPUC California Public Utilities Commission
DFG California Department of Fish and Game
DG distributed generation
DOE United States Department of Energy
DRECP Desert Renewable Energy Conservation Plan
EISG Energy Innovations Small Grant
EPIC Electric Program Investment Charge
FDD fault detection and diagnostics
GHG greenhouse gas
GWh gigawatt hour(s)
HEED Home Energy Efficient Design
HVAC heating, ventilation, and air conditioning
IAW industrial, agriculture, and water
IEPR *Integrated Energy Policy Report*
IP intellectual property
IT information technology
kW kilowatt(s)
kWh kilowatt hour(s)
LED light-emitting diode
MTG microturbine generator
MW megawatt(s)
MWh megawatt hour(s)
NOx nitrogen oxide
OIR Order Instituting Rulemaking
PAGs Program Advisory Groups
PEV plug-in electric vehicle
PGC Public Goods Charge
PHEV plug-in hybrid electric vehicle
PIER Public Interest Energy Research

PV photovoltaic
R&D research and development
RD&D research, development, and demonstration
RESCO Renewable Energy Secure Community
RPS Renewables Portfolio Standard
SB Senate Bill
SDG&E San Diego Gas & Electric
UCSD University of California, San Diego
WESTCARB West Coast Regional Carbon Sequestration Partnership