CALIFORNIA
ENERGY
COMMISSION

In The Public Interest
Developing Affordable, Clean, and Smart Energy For 21st Century California

STAFF REPORT
DRAFT

March 2007
CEC-500-2007-020-SD

Arnold Schwarzenegger, *Governor*

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ABSTRACT

In 1996, the Legislature established the Public Interest Energy Research Program at the Energy Commission. The program is funded with payments from electricity and natural gas ratepayers. PIER works to develop technologies and information that will address critical public interest needs. Since the inception of the PIER Program, the Energy Commission has supported research and development for buildings efficiency, energy systems integration, renewable energy resources, advanced generation, environmental research, transportation, and efficient technologies for industry, agriculture, and water. This overview presents the program's benefits and highlights active and completed research.

KEYWORDS

California Energy Commission, Public Interest Energy Research, PIER, Research and Development, RD&D, Buildings Efficiency, Energy Systems Integration, Renewable Energy Resources, Industry, Agriculture, Water, Environmentally Preferred Advanced Generation, Environmental Research, Transportation, Climate Change

ACKNOWLEDGEMENTS

The *2007 PIER Annual Report* was prepared with contributions from the following:

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IN THE PUBLIC INTEREST
Developing Affordable, Clean, and Smart Energy For 21st Century California

In 2006 the state Legislature enacted Senate Bill 1250 (Chapter 512, Statutes of 2006), which reauthorizes and extends California's Public Interest Energy Research (PIER) Program from 2007 through 2011. As the agency responsible for administering the PIER Program, the California Energy Commission looks forward to implementing this critical energy research, development, and demonstration (RD&D) effort over the next five years.

In accordance with Public Resources Code Section 25620.8, the Energy Commission hereby submits to the state Legislature its 2006 Annual Report regarding the PIER Program. This report, titled *In the Public Interest: Developing Affordable, Clean, and Smart Energy for 21st Century California*, responds directly to SB 1250 and other energy-related laws passed by the California Legislature in 2006, and shown in Table 1.

There are three sections in this report. Section I provides an overview of how the Energy Commission will administer the PIER Program to accomplish the directives contained in SB 1250. Section II highlights specific RD&D projects that will directly impact the state's energy markets with new commercial products and services. Section III presents the complete portfolio of RD&D projects funded through the PIER Program. This section contains individual project descriptions that explain specific active and completed research accomplishments.

The passage of SB 1250, AB 32, and other major pieces of legislation have set the stage for the Energy Commission to move in new directions with newly articulated mandates on state energy RD&D.

Table 1 – Energy Legislation

Major New Laws Affecting the Energy Commission in 2006

AB 32 (Núñez, Chapter 488, Statutes of 2006): Requires California to reduce its statewide greenhouse gas emissions back to 1990 levels by 2020. The law requires that the California Air Resources Board prepare an emissions reduction plan by 2008 and that corresponding regulations then be adopted by 2011.

AB 1632 (Blakeslee, Chapter 722, Statutes of 2006): Requires the Energy Commission to compile and assess existing scientific studies for potential vulnerability of large baseload facilities, and assess key planning and policy issues affecting the future role of nuclear power plants.

AB 1925 (Blakeslee, Chapter 471, Statutes of 2006): Requires the Energy Commission to prepare a legislative report with recommendations on geologic sequestration of carbon dioxide.

AB 2021 (Levine, Chapter 734, Statutes of 2006): Requires the Energy Commission and the California Public Utilities Commission (CPUC) to set targets for statewide efficiency savings for publicly owned and investor owned utilities in a public process.

AB 2160 (Lieu, Chapter 742, Statutes of 2006): Requires the Energy Commission to identify and develop appropriate incentives to facilitate state and commercial building energy and resource efficient projects.

AB 2189 (Blakeslee, Chapter 747, Statutes of 2006): Requires the Energy Commission to revise the interim Rewewables Portfolio Standard (RPS) tracking methodology to verify procurement from eligible small hydroelectric generation facilities.

AB 2778 (Lieber, Chapter 617, Statutes of 2006): Requires the CPUC, in consultation with the Energy Commission, to administer a self-generation incentive program for distributed generation resources and limit eligibility for non-solar technologies to fuel cells and wind technologies that meet or exceed the emissions standards adopted by the California Air Resources Board (CARB).

SB 1 (Murray, Chapter 132, Statutes of 2006): Implements the California Solar Initiative (CSI), with a goal to install 3,000 megawatts of solar energy systems on new and existing residential and commercial customer sites by 2017. The Energy Commission will be contributing $400 million to this $3 billion program and will also establish energy efficiency improvements for new or existing homes and commercial structures that install new solar systems.

SB 107 (Simitian, Chapter 464, Statutes of 2006): Revises California's RPS by accelerating the 20 percent renewable energy target from 2017 to 2010. The bill also amends current law governing the administration of Energy Commission’s PIER and Renewable Energy Programs.

SB 1059 (Escutia, Chapter 638, Statutes of 2006): Authorizes the Energy Commission to designate transmission corridors for future use and designates the Commission as the lead agency for the California Environmental Quality Act (CEQA) for the proposed corridors.

SB 1250 (Perata, Chapter 512, Statutes of 2006): Reauthorizes the Energy Comission’s PIER Program and the Renewable Energy Program for five years along with allocating the funding for these programs.

SB 1368 (Perata, Chapter 598, Statutes of 2006): Requires the Energy Commission to develop and adopt a greenhouse gas emissions performance standard for long-term procurement of electricity by local publicly owned utilities.

Section I: An Overview of the PIER Program

A. Creation and Initial Purpose of the PIER Program

The State Legislature created the PIER Program in 1996 when it enacted AB 1890 (Chapter 854, Statutes of 1996), California's utility restructuring legislation. This law required that $62.5 million be collected annually from the three investor-owned electric utilities and deposited in the Public Interest Energy Research and Development Account, to be invested by the Energy Commission for energy-related RD&D efforts that serve the greater public interest. In doing so, administration of public interest RD&D was shifted from California's investor-owned utilities to state government, a major change intended to ensure an appropriate role for public interest energy research in a newly competitive energy marketplace.

The Legislature explicitly defined the meaning of public interest energy RD&D. The following three principles, contained in Public Resources Code Section 25620 *et seq*., have guided the Energy Commission's investments since the PIER Program's inception:

- Provide environmentally sound, safe, reliable, and affordable energy services and products;
- Support RD&D not adequately provided by competitive *or* regulated energy markets;
- Advance energy science and technology to the benefit of California's ratepayers.

Expectations for success of the PIER Program were high from the very start as the Energy Commission built upon earlier RD&D efforts dating back to the late 1970s, which helped create today's energy efficiency and renewable energy industries. When the PIER Program began in 1997, the Energy Commission determined that a strategic plan was needed to implement its responsibilities for public interest research. After conducting a series of statewide collaborative public hearings to gather input from stakeholders and interest groups, the Energy Commission adopted its first strategic plan.

While much of the initial RD&D carried out through the PIER Program focused primarily on electricity-related applications, the Energy Commission was given authority to expand the scope of its public interest RD&D efforts. AB 1002 (Chapter 932, Statutes of 2000) granted the CPUC the authority and discretion to determine the appropriate funding levels for natural gas, energy efficiency, and public interest RD&D activities. On August 19, 2004, the CPUC adopted Decision 04-08-010 that established the funding level for natural gas public interest RD&D,

identified the Energy Commission as the administrator of the natural gas funds, and established the administrator's responsibilities. The *2007-2011 Natural Gas Research Investment Plan* was developed to capture the synergies between natural gas and electricity research and outlines the PIER Natural Gas Program's strategic priorities and research solutions. Additionally, the Energy Commission staff prepares an annual report summarizing the programs' research progress and budget status for review and approval by the CPUC. Recently, SB 1250 shifted this program from annual to fiscal reporting. Today, with funding support from natural gas and electricity ratepayers, the PIER Program is the nation's largest state energy RD&D effort with approximately 297 active and 464 completed research activities.

B. The Legislature's New Directions for the PIER Program

In reauthorizing funding for the PIER Program from 2007 to 2011, state lawmakers also provided significant new direction, focus, and priority to the Energy Commission in administering the PIER Program.

Specifically, SB 1250 emphasizes that the Energy Commission should develop science, technology, and knowledge that will directly impact the state's energy markets with new commercial products and services. The legislation confirms that energy efficiency remains the state's electricity resource of first choice and places a new importance on reducing water consumption and addressing other energy-related impacts on California. Reducing greenhouse gas emissions also is a top consideration, as is the establishment of a transportation element within the PIER Program. Each of these major new public policy thrusts will be reflected in the selection of future RD&D projects.

SB 1250 expressly established a new general goal, and four new specific goals, to guide future RD&D investments by the Energy Commission. The general goal is to:

> *"Develop and help bring to market energy technologies that provide increased environmental benefits, greater system reliability, and lower system costs."*

The specific goals are to develop and help bring to market:

- *"Advanced transportation technologies that reduce air pollution and greenhouse gas emissions beyond applicable standards, and that benefit electricity and natural gas ratepayers."*

- *"Increased energy efficiency in buildings, appliances, lighting, and other applications beyond applicable standards, and that benefit electric utility customers."*

- *"Advanced electricity generation technologies that exceed applicable standards to increase reductions in greenhouse gas emissions from electricity generation, and that benefit electric utility customers."*

- *"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."*

The Energy Commission is currently planning and will soon convene an advisory board as directed by SB 1250. This board will guide the Energy Commission's selection of RD&D programs and projects.

C. Comprehensive and Coordinated Portfolio of Projects

SB 1250 directs the Energy Commission to take a portfolio approach to RD&D that provides tangible energy and environmental benefits to the state's electricity and natural gas customers. A portfolio approach reduces risks and increases diversity when developing new solutions to California's energy challenges. The concept of a RD&D portfolio has, in fact, guided Energy Commission RD&D funding decisions over the past few decades. The current approach spans near-term, mid-term, and long-term planning horizons, managing risk and rewards of RD&D investments by taking a holistic and integrated approach coordinated with other state agencies and regulatory programs.

To implement the interrelated policies and goals established by the Legislature, the PIER Program is organized into the following seven coordinated program areas:

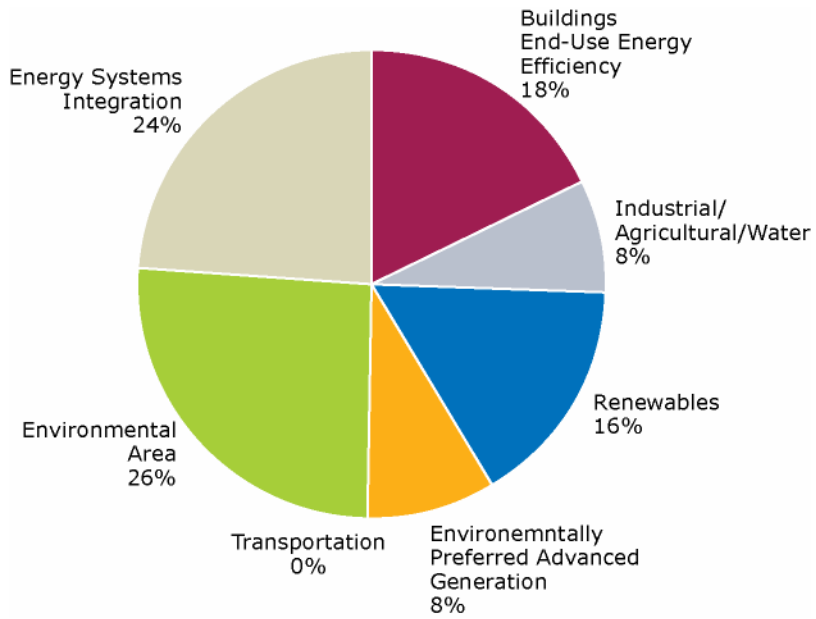
- Buildings End-Use Efficiency
- Industry, Agriculture and Water
- Renewable Energy Resources
- Environmentally Preferred Advanced Generation
- Transportation
- Environmental Research
- Energy Systems Integration

In addition to these research areas, the Energy Commission also operates an Energy Innovation Small Grants (EISG) program, which provides early seed money for new ideas in all of the above areas.

With a wide portfolio of projects representing approximately $500 million in RD&D investments, the Energy Commission prioritizes research funding according to California's "loading order" for new electricity resources as established in the state's *Energy Action Plan* and the Energy Commission's *Integrated Energy Policy Reports*. This loading order puts energy efficiency and demand response resources first in line to meet new demand and supply needs, followed by renewable energy resources, and then clean fossil fuel and distributed generation technologies. The loading order also recognizes economic as well as environmental and social costs.

Figure 1 illustrates how the Energy Commission has distributed its RD&D investments among its seven PIER Program Areas in response to policy objectives provided by the Governor and the Legislature.

Figure 1
Comparison of Research Funding by PIER Program Area



During the last five years, approximately 70 percent of PIER funding has focused on research that supports the loading order, which stresses energy efficiency and renewable energy technologies followed by infrastructure improvements. The bulk of the remaining funds have addressed energy infrastructure system issues and the environmental impacts of energy, including air quality, land-use patterns, biological diversity, clean water, and global climate change.

D. Budget and Project Development Process

In the upcoming 2007-08 fiscal year, the Energy Commission has proposed an $80.5 million appropriation to fund both electricity ($62.5 million) and natural gas ($18 million) RD&D projects. The Energy Commission is committed to allocating these funds according to the legislative intent expressed in SB 1250.

The PIER Program is administered by Energy Commission staff under the direction and oversight of the five-member Commission. The Energy Commission has established an RD&D Committee, consisting of two of its five Commissioners, to provide detailed policy direction for the program. The Committee is chaired by the Engineer/Scientist member of the Commission with a second member appointed by the Chairman. The Committee reviews and

recommends all activities before recommending approval by the Energy Commission at a business meeting.

The RD&D Committee conducts an annual budget review of the PIER Program in the spring before the beginning of each fiscal year. This Committee examines the status and progress of earlier investments for the coming fiscal year and establishes initial target levels for the seven PIER Program Areas. These allocations are based on legislation, executive orders, Energy Commission integrated energy policy reports, and the loading order. The RD&D Committee also establishes a limited reserve that can be allocated during the fiscal year for technical opportunities that arise due to unexpected technical progress or that cut across two or more of the seven program areas. An example of the latter is advanced energy storage technologies, which are of interest to the program areas of renewables, energy systems integration, and industrial efficiency.

Throughout the year, the Energy Commission staff carries out program and project development activities within the budget allocations established by the RD&D Committee primarily through grant or contract solicitations. In addition to grant and contract solicitations, the Energy Commission may enter into sole-source agreements. In large measure, this authority is used to support new or follow-up activities with researchers who were successful in previous solicitations. Development of expertise is often gradual and cumulative and the best results may come from funding follow-up research. Proposed projects from all solicitations are presented to the RD&D Committee for review before being presented to the Energy Commission for funding approval at a public business meeting.

E. Partnerships Are Key to Doing Business at the Energy Commission

When looking for RD&D performers, the Energy Commission seeks the best qualified researchers to do the right research for the greatest benefit to the State of California. Creating and sustaining effective research partnerships is an essential element for achieving this goal.

The Energy Commission relies upon strategic partnerships to avoid duplication, build on successful RD&D work, generate new ideas, leverage both public and private investments, and ensure that each RD&D project funded by the Energy Commission provides benefits to the state’s electric and natural gas ratepayers as well as utilities. This approach allows the diverse realm of California RD&D experts to do what they do best: solve problems based on maximizing expertise and collaboration.

The Energy Commission has forged partnerships with other state agencies including the Department of General Services (DGS), Department of Finance, the California Air Resources Board (CARB), the California Department of Forestry, the California Environmental Protection Agency (CalEPA), and the Integrated Waste Management Board. The Energy Commission has also entered into strategic alliances with private sector organizations such as California builders,

the Collaborative for High Performance Schools, the California Commissioning Collaborative, and major equipment manufacturers. Equally important, the Energy Commission continues to tap into California's diverse and substantial research capabilities at the state's universities, national laboratories and high-tech companies. All of these efforts are intended to leverage and complement federal RD&D investments relevant to California's energy markets.

F. New Opportunities for RD&D Partnerships

Building on this firm foundation of strategic and cost-effective collaboration, the Energy Commission continues to establish new market-focused partnerships to advance cutting-edge technologies and to bring forward critical information to decision makers to help shape future state energy policy. SB 1250 and other recent legislation require the Energy Commission to coordinate with the CARB on new transportation RD&D efforts and the CPUC on the California Solar Initiative (CSI). Following is a description of the Energy Commission's early investment decisions for these activities as examples of our collaborative efforts.

Collaborative Efforts Concerning Transportation RD&D

Collaboration with CARB and other state agencies is critical for the development of new technologies to help California meet its aggressive greenhouse gas emission reduction targets.

From the mid-'80s through mid-'90s, the Energy Commission made RD&D investments in electric vehicle research as well as methanol and other alternative transportation fuel options. In 2005, SB 76 (Chapter 91, Statutes of 2005) gave the Energy Commission new authority to use its electricity and natural gas funds for transportation RD&D, that provides results and benefits to the electricity and natural gas ratepayers.

SB 76 also directs the Energy Commission to plan its natural gas RD&D efforts with CARB. Connecting of electricity and natural gas systems to broader energy considerations in the transportation sector offers a golden opportunity: to make technology investments with both its electricity and natural gas funds and to develop technologies and knowledge that offer integrated benefits to California's entire energy system. The Energy Commission's new focus on transportation RD&D will encompass innovations in motor vehicle efficiency, alternative fuels, transportation system planning issues associated with fleet and mass transit systems, and regional and community level transportation planning.

One of the first RD&D ventures in the Transportation Research Area is development of a *Natural Gas Vehicle Research Roadmap* that will address the energy efficiency of natural gas vehicles, technology cost effectiveness and reducing emissions to meet California's air quality standards. CARB will be an integral partner in identifying the critical steps needed to put natural gas vehicles onto California's roads in the near future.

The Energy Commission has worked closely with the CARB to identify 13 RD&D transportation projects totaling $3.2 million, to be funded by the natural gas funds. Among the key issues being explored by these projects are fine particulate matter pollution, radical efficiency upgrades, and biodiesel fuel.

Using its electricity RD&D funds, the Energy Commission established the Plug-In Hybrid Electric Vehicle Research Center at the Institute of Transportation Studies of the University of California, Davis. Funded with an initial grant of $3 million, this Center will examine the potential impacts of electric vehicle charging on the electricity grid, identify the RD&D necessary to address how plug-in hybrids can be part of the state's solution to global climate change and other energy-related issues, and develop multi-institutional partnerships to leverage the Energy Commission's investment and maximize benefits for California ratepayers.

The Energy Commission also released a $3 million grant solicitation for transportation bio-fuels resulting in three proposed research awards to market acceptance of biofuels in California. The research includes RD&D advancements on promising biofuel technologies and biorefineries for the production of transportation fuels such as ethanol and biodiesel. The research will additionally co-produce other value-added products such as biobased chemicals, heat and power. These research projects will be co-located and integrated with existing and new biomass production facilities that will reduce the production costs for both facilities and provide ratepayer benefits. Co-location or integration will create new sources of revenue for the biomass power facilities through sales of electricity and steam to the biofuel facilities and reduce fuel costs through sharing the biomass feedstocks with the biofuel facilities. These projects will help to meet the goals of the Governor's Executive Order S-06-06, the Bioenergy Action Plan, and AB 32. These three projects will provide a new and more economical alternative that will make California's biomass power facilities more competitive in the future electricity market, thereby contributing to a cleaner and more diversified energy supply.

Collaborative Efforts Concerning Solar Photovoltaic RD&D

An intensive stakeholder engagement process, similar to the PIER Photovoltaic (PV) Research Plan with the CPUC, is critical to a successful planning process that meets the state's renewable energy policy goals.

Senate Bill 1 (Chapter 132, Statutes 2006) created the California Solar Initiative (CSI), which requires the CPUC and the Energy Commission to coordinate their respective solar programs to reach a goal of 3,000 megawatts (MW) of new solar-produced electricity by 2017. This requirement represents the largest public investment in solar photovoltaic (PV) in the history of the United States. SB 1 also authorized the CPUC to establish a $50 million, 10-year RD&D program in support of the CSI and to coordinate this RD&D effort with the Energy Commission.

In 2006, the Energy Commission convened an RD&D planning process with the CPUC and major stakeholders in the solar energy industry, including private and

public utilities, solar manufacturers and installers, the federal government, environmentalists, and consumers. All told, 17 stakeholder organizations participated (see Table 2). This process helped coordinate solar PV RD&D funded by the Energy Commission with other major solar technology commercialization programs being launched at the CPUC.

Table 2

PV Research Plan Stakeholder Organizations
Energy Commission Renewables Program
CPUC Staff
CPUC President
Pacific Gas and Electric
Southern California Edison
San Diego Gas and Electric
Sacramento Municipal Utility District
U.S. Department of Energy
National Renewable Energy Laboratory
Vote Solar
Clean Energy States Alliance
Consol
California Solar Energy Industries Association
SunPower
Powerlight
NanoSolar
University of California-Merced

The development of a solar *PIER PV RD&D Roadmap* helped identify critical milestones as well as RD&D priorities of value to both the Energy Commission and CPUC programs. Coordinating each agency's respective solar funding was also explored. Instead of early stage research, stakeholders placed a higher value on later-stage technology advances to help get products over the last commercialization hurdles and into the market. The process culminated in a public forum at the Solar 2006 Conference held in San Jose in October 2006.

CPUC representatives have acknowledged that this process helped put state solar RD&D into a larger context. The CPUC staff paper on its solar RD&D program released in February 2007 referred extensively to the PIER road mapping process. Energy Commission staff has worked with the CPUC on its approach for managing the CSI research program.

The resulting *PIER PV Research Plan* is an important guide for future research funding decisions at the Energy Commission and CPUC on solar RD&D. The Energy Commission will proceed with a similar stakeholder engagement process for each renewable energy sector, integrating the state's RD&D on renewable resources with state policies such as the Renewables Portfolio Standard.

Section II: RD&D Highlights Summary

To meet the goals of SB 1250, the Energy Commission will establish new ways to work with public and private entities to deliver even more value to ratepayers, the state's energy infrastructure, and the environment. For example, RD&D funded by the Energy Commission is providing information and tools for better decision-making by individuals and state policy makers; energy design tools for architects and engineers; wind and solar resource assessments for developers and utilities; and environmental research to better understand and reduce impacts of advanced supply technologies, such as "once-through" cooling for conventional electricity generation. These highlighted activities demonstrate important progress toward the new goals established by the California Legislature in SB 1250.

The Energy Commission research profiled in the following 10 "Highlights" show how RD&D activities through the PIER Program meet the new general and specific policy goals outlined in SB 1250. These Highlights display the diversity of RD&D performed at the Energy Commission. Whether helping to accelerate renewable energy deployment, maintain the integrity of our electricity grid, or provide the science to inform policies to address global climate change, the Energy Commission's RD&D efforts have created a platform to promote further progress in achieving and maintaining a clean, reliable, and affordable energy supply. The highlights and the goals they address are outlined below.

1. **Systems Thinking in Lighting (Buildings Efficiency):** Research on super-efficient lighting systems for classrooms, kitchens, hotels, and other institutional settings such as senior living centers is profiled. Profiled RD&D meets SB 1250's specific goals of *"increased energy efficiency in building, appliances, lighting and other applications beyond applicable standards and that benefit electricity customers."*

2. **Darker-Colored Cool Roofs for Homeowners (Buildings Efficiency):** Research on developing darker-colored cool roof products to help reduce residential air-conditioning loads is described. This RD&D meets SB 1250's specific goal of *"increased energy efficiency in building, appliances, lighting and other applications beyond applicable standards and that benefit electricity customers."*

3. **New Tools for Managing Peak Demand (Energy Systems Integration):** Highlights two peak electricity demand reduction tools being developed with Energy Commission funding. The AutoDR project is developing and demonstrating technologies for automating demand responses, and DRBizNet is a software tool that is being developed to streamline the implementation and coordination of peak demand reduction programs for utilities and their customers. Both projects meet SB 1250's specific goal of *"reducing energy use in buildings…beyond applicable standards, and that benefit electric utility customers."*

4. **Enhancing Transmission Capabilities (Energy Systems Integration):** Research on three different technologies is profiled, each designed to increase the reliability of California's transmission grid. All three technologies – the Sagging Line Mitigator, the Real-Time Monitoring/Dynamic Rating System, and the Flywheel Energy Storage System – meet the specific goals of SB 1250 to *"advance electricity technologies that…improve transmission or distribution of electricity…".*

5. **Maximizing Ratepayer Value with New Renewable Resources (Energy Systems Integration):** Research methodologies are described that strategically maximize the benefits of new renewable resources to boost overall system reliability. This research, which falls under the broad umbrella of Strategic Value Analysis, meets SB 1250's specific goals to bring to market *"advanced electricity technologies that…improve transmission or distribution of electricity generated from renewable energy resources."*

6. **Wind Power Improvements (Renewable Energy Resources):** Research is described that impacts wind power development in California. The first example is a wind forecasting program that reduces costs of providing transmission access to wind projects. The second example highlights RD&D to improve wind turbine durability and ability to harness energy from lower wind speed areas. Both of these examples meet SB 1250's specific goal of bringing to market *"advanced electricity generation technologies that exceed applicable standards to increase reductions in greenhouse gas emissions from electricity generation, and that benefit electric utility customers."* They also meet SB 1250's goal of advancing *"electricity technologies that reduce or eliminate consumption of water and other finite resources, increase use of renewable energy resources, or improve transmission and distribution of electricity generated from renewable energy resources."*

7. **Fostering Industry Use of Efficient Technologies (Industry, Agriculture, Water):** Two technologies are profiled. The first reduces energy consumption and processing time at the state's wineries, while the second features a new technology that reduces energy consumption at food processing and other industrial sites. Both RD&D efforts comply with SB 1250's specific goal to help bring to market *"increased energy efficiency in building, appliances, lighting and other applications beyond applicable standards and that benefit electricity customers."*

8. **Transforming Wastes into Clean Energy (Renewable Energy Resources):** Two projects developed in the Central Valley transform waste into clean electricity. The landfill bioreactor and a technology that turns wastewater into fuel for a micro-generator meet SB 1250's specific goals to help bring to market *"advanced electricity generation technologies that exceed applicable standards to increase reductions in greenhouse gas emissions from electricity generation, and that benefit electric utility*

customers." They also meet SB 1250's specific goal of advancing *"electricity technologies that reduce or eliminate consumption of water and other finite resources, increase use of renewable energy resources, or improve transmission and distribution of electricity generated from renewable energy resources."*

9. **Developing Ultra-Clean Fossil Fuel Generation Systems (Environmentally-Preferred Advanced Generation):** Two technologies are profiled. The first involves a combustion system based on rocket engine designs that can be used to build a zero-emissions power plant. The second involves several firms developing an ultra-clean gas turbine that can satisfy stringent California emissions standards and be used in efficient industrial combined heat and power applications. Both of these technologies meet SB 1250's specific goal to help bring to market *"advanced electricity generation technologies that exceed applicable standards to increase reductions in greenhouse gas emissions from electricity generation, and that benefit electric utility customers."*

10. **Assessing Climate Risks and State Policy Responses (Environmental Research):** This Highlight describes the evolution of the California Climate Change Center and the key role that Energy Commission's PIER Program research played in the development of the first Climate Action Plan and the Global Warming Solutions Act of 2006 (AB 32). This cutting-edge research supports the overall desire expressed in SB 1250 to put in place policies that advance *"electricity generation technologies that exceed applicable standards to increase reductions in greenhouse gas emissions from electricity generation, and that benefit electric utility customers."*

Section III. Portfolio of Energy Commission RD&D

The complete Energy Commission RD&D portfolio is contained on the enclosed CD. A searchable and updated version of the portfolio can be found on the Energy Commission website at: www.energy.ca.gov/pier/documents/index.html. This portfolio contains summaries of the RD&D activities undertaken by the Energy Commission and is organized by 10 main categories and more than 70 subcategories. This section contains summaries for approximately 297 active and 464 complete research activities.

Research Categories for the 2006 Annual Report Write-up Section

Environmental Effects of Energy Activities

Aquatic Resources

Improving Forecasting for Enhanced Hydropower Generation

Improving Water and Energy Management

Reducing the Impacts of Electricity Generation

Air Quality

- Distributive Generation
- Indoor Air Quality
- Modeling
- Natural Gas Interchangability

Land Use and Habitat

- Avian Electrocution and Collision
- Effects of Renewable Generation
- Habitat Impacts
- Siting Facilitation
- Urban Planning and Sustainable Communities

Global Climate Change

- Climate Monitoring, Analyses, and Modeling
- Impact and Adaptation Studies
- Inventory Methods
- Options to Reduce Greenhouse Gas Emissions
- The Economics of Climate Change

Transportation

Energy Systems

Economic and Policy Research

Demand Response

Distributed Energy Resources

Reliability

Security

Customer Energy Use

Agriculture

Commercial and Residential

- Building Design
- Building Envelope
- Codes and Standards Support
- Equipment and Appliances
- Heating, Ventilation, and Air Conditioning
- Lighting

Industrial

- Data Processing and Laboratories
- Energy Use Benchmarks
- Load Management and Peak Demand Reduction
- Motors, Pumps, and Drives
- Power Quality
- Process Heating (Boilers, Furnaces, and Heat Exchangers)
- Refrigeration and Cooling

Transportation

Water Transport and Treatment

Electricity Transmission, Distribution, and Storage

Electricity Transmission

Electricity Distribution

Electricity Storage

Energy Production from Renewable Resources

Economic, Policy, and Technology Transfer Research

Biogas, Biomass, and Landfill Gas

Geothermal

Hydropower

Ocean

Solar

Wind

Renewable Resource Processing and Fuel Transmission, Distribution, and Storage

Alternative Transportation Fuels

Renewable Resource Exploration and Extraction

Geothermal

Ocean

Wind

Energy Production from Non-Renewable Resources

Economic and Policy Analysis of Potential Energy Resources

Combined, Cooling, Heat and Power (Cogeneration, CHP, CCHP)

Fuel Cells

Internal Combustion Engines

Stirling Engines (External Combustion Engines)

Turbines

Power Plants

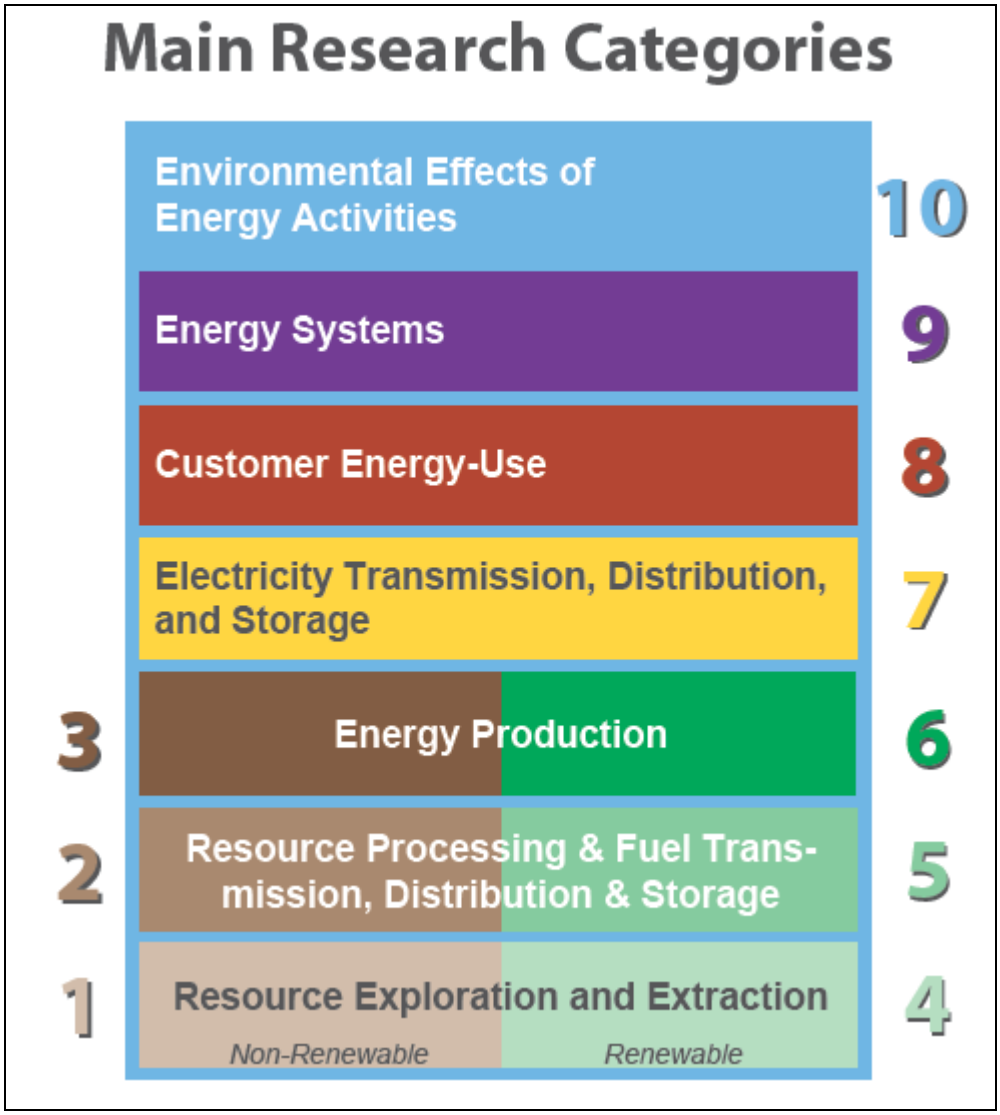
Non-Renewable Resource Processing and Fuel Transmission, Distribution, and Storage

Alternative Transportation Fuels

Natural Gas Transmission, Distribution, and Storage

Non-Renewable Resource Exploration and Extraction

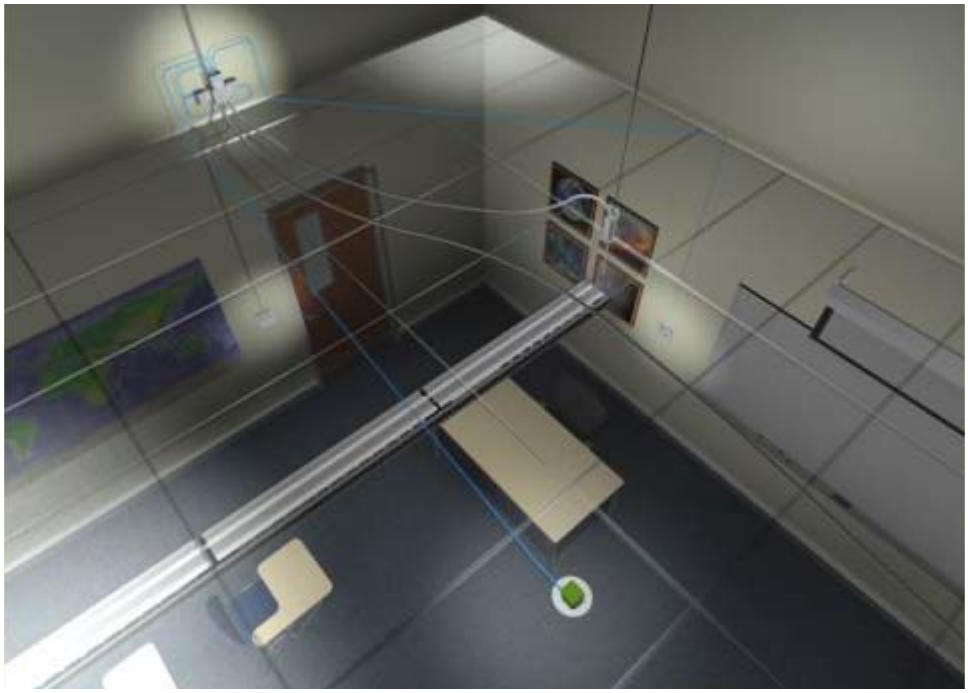
Oil Extraction


Main Research Categories
Environmental Effects of Energy Activities
10
Energy Systems
9
Customer Energy-Use
8
Electricity Transmission, Distribution, and Storage
7
3
Energy Production
6
2
Resource Processing & Fuel Trans-mission, Distribution & Storage
5
1
Resource Exploration and Extraction
Non-Renewable
Renewable
4

1. SYSTEMS THINKING IN LIGHTING

Systems thinking helps bring a “big picture” perspective to solving long-standing energy, environmental, and economic challenges. When it comes to energy, relying upon a “systems approach” dovetails with the mission of the California Energy Commission’s PIER Program to fill the gaps in research needed to bring affordable, reliable, and clean energy solutions to market.

A key challenge in reducing energy consumption in buildings is the fact that different manufacturers and service companies sell discrete components that then have to be assembled into a complete lighting system. This disconnected approach increases costs, complexity, and the probability of technical glitches. Taking a systems approach to lighting challenges can integrate efficiency and cost savings into lighting arrays from the start and multiply benefits when these integrated systems are then distributed throughout the marketplace.



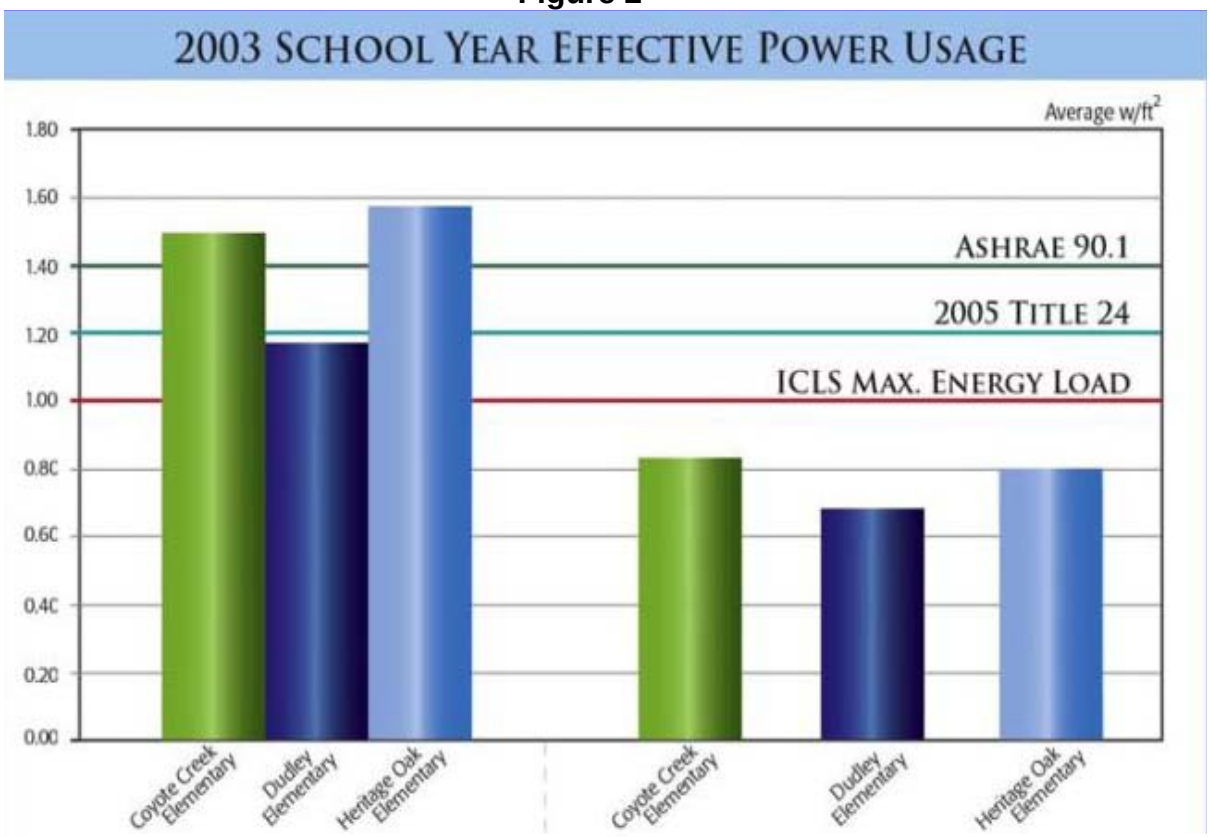
Example of system approach to lighting. All components are designed for quick installation (plug-and-play) and to work together to provide optimal task-specific illumination, high quality light, and energy savings. Notice the sensor (green box bottom center of the picture), which automatically controls lights to meet desired illumination levels. Adding demand response capability would enable lighting levels during peak demand for electricity to be adjusted.

The reason the Energy Commission chose to fund each of the following three packages of lighting technologies can be summed up in one sentence: *Each introduces substantial benefits and energy savings that go beyond state standards, can be integrated almost seamlessly into the marketplace, and addresses key state policy goals.*

Integrated Classroom Lighting Systems: Lighting in traditional classrooms was basically a simple "on-off" approach with no provisions for computer or audio-visual (A/V) technologies. The controls were by the classroom door instead of being located near the teacher's work location. The only alternative was a custom design that combined luminaires with sensors and complex, computerized controls that carried a price tag beyond the budgets of most school systems.

Funded through the PIER Buildings Program, Finelite, Inc., based in Union City in California's East Bay, undertook development of a set of lighting design guidelines and standards that meet the needs of today's high-performance classrooms. With the help of over 100 experts in engineering, education, and energy, an "Integrated Classroom Lighting System" (ICLS) was developed that can cut energy consumption in classrooms in half while cost-effectively delivering the lighting and controls needed for today's high-performance classrooms. With funding from the Energy Commission PIER Program, Finelite was able to take ICLS through three different generations of technology development, ultimately producing a commercial system that is being used in California, New York, New Jersey, and Pennsylvania.

Figure 2



Non-Integrated Classroom Lighting System Integrated Classroom Lighting System

Private-Public Partnerships: Sharing the Risk to Explore the Potential of Promising Technologies, Concepts, Ideas, Etc.

The risk involved with private investment in RD&D can prevent good technologies from being developed, as failure contributes only valuable knowledge of what does not work. Einstein put the risk in research into perspective when he said, “If we knew what we were doing, it wouldn't be called research, would it?” RD&D failures are very valuable for future product development, but only for those companies not financially crippled in the process of discovering said knowledge. With help from the public sector, RD&D on promising but unknown technologies like integrated classroom lighting systems are being explored. New technologies have the potential to save consumers money and increase quality of life, while potentially rewarding private sector investors with a first-to-market advantage, bragging rights and status as a role model at an acceptable risk level.

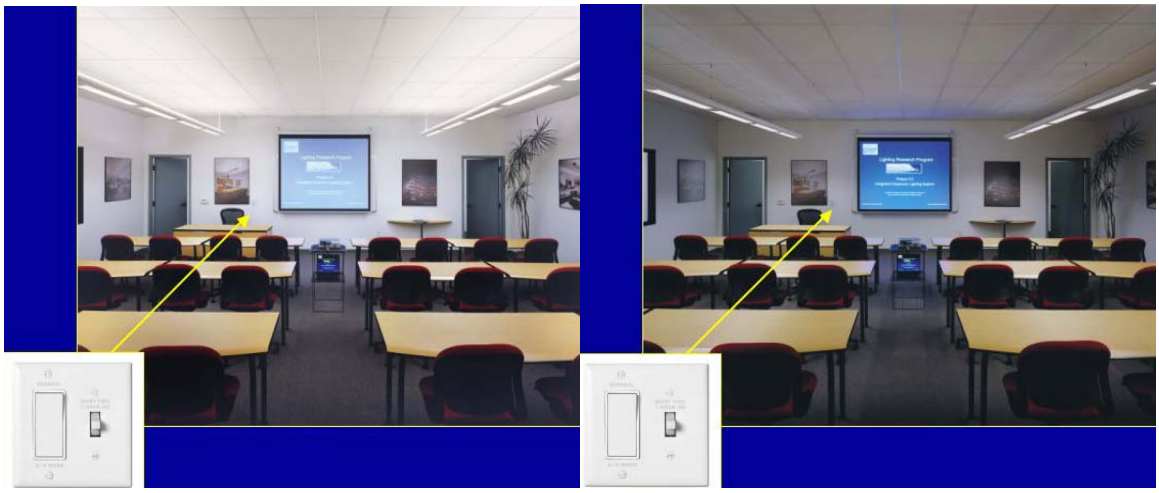
With this shared risk approach to RD&D in mind, the Energy Commission ($170,000) and Finelite ($125,000) undertook a joint research project with the following goals:

- Analyze trends in computer and audiovisual technologies to project how they affect tomorrow’s lighting needs.
- Develop criteria for rating lighting systems according to efficiency, luminescence, and other factors.
- Incorporate impacts of recent laws and regulations governing energy efficiency into design and funding approach considerations.
- Insure that total system costs should fall within current school budget constraints of all socio-economic regions in California.
- Generate a public domain model for super-efficient school lighting systems.

“Many schools have leaking roofs and other priorities. That’s why this system has to deliver energy savings and be affordable from the start.” Terry Clark, president of Finelite, Inc. “What’s so nice about the ICLS is that we don’t have to force it on California school districts. They welcome it. It helps cut their utility bills, freeing up funds that can finally take care of their curriculum needs,” said Clark.

The biggest surprise to emerge from this research project -- which also involved Southern California Edison and the Los Angeles Unified School District -- was the convergence of opinion about the best design. Whether one was focused on energy savings, an improved learning experience, or teacher convenience, all solutions pointed to the same basic framework:

- Employ a Teacher Control Center for all lights at the front of the classroom to make it easier for teachers to regulate best practice lighting;
- Make lighting systems “plug and play,” requiring no customized parts or non-standardized installation procedures;
- Reduce rows of overhead lights from three to two rows, cutting costs by 30 percent, while actually improving the student learning environment;
- Incorporate strategic day lighting wherever and whenever possible in the design of new classrooms.



Notice the sharper screen when lights are dimmed via the lighting control behind the teacher’s desk. Enough light is still available for note taking.

The statewide potential for energy savings with these school lighting systems is staggering. Deployment of an ICLS in each of California’s K-12 classrooms would reduce daily electrical demand on the statewide grid by an amount equivalent to not building a new 300-MW fossil fuel power plant.

> “Our instructors and students really enjoy the new systems. We are planning more ICLS installations around campus.”
>
> Victor Lai
> Energy Manager
> San Francisco State University

This school lighting package is now being marketed nationally as a cost-effective way to save energy and to give teachers a new tool to help successfully introduce and use digital and audiovisual technologies in high-performance classrooms. Surveys show teachers prefer the new more efficient lighting systems by a ratio of 9 to 1. The Illuminating Engineering Society of North America describes this PIER-funded project as representing “unique and significant advancements to the art and science of lighting.”

Students also give the lighting systems superior marks. The New York State Energy Research and Development Authority (NYSERDA) is now testing the

ICLS to quantify the advantages in the learning experience of children and adults. The NYSERDA project will help California utilities and schools learn more details about the value ICLS brings to the classroom experience.

Safer and Smarter Bathroom Lighting: Bathroom lights in hotels, senior living centers, nursing homes, and dormitories often stay on from 5 to 12 hours on any given day of occupancy. Bathroom lights may be left on for a variety of reasons:

- Plain old forgetfulness;
- To provide a guide to the bathroom at night.

Through work funded by the Energy Commission's PIER Program, lighting researchers have learned that 75 percent of hotel bathroom lighting energy is consumed when lights are left on for more than one hour, much longer than most people use the bathroom. Occupancy sensors can solve this problem, but managers at lodging and housing institutions have been reluctant to install them for fear of accidental shut-offs when the bathroom is occupied. Energy Commission-funded research has addressed the concerns of managers by developing two products that feature the option of a time-out period significantly longer than most occupancy sensors, thus lessening the chance of leaving occupants in the dark.

California Lighting Technology Center

Designing commercial solutions to our lighting conundrums is the California Lighting Technology Center (CLTC), a consortium of academics, industry, utility, and non-profit research organizations housed at the University of California, Davis. With $1.5 million in initial funding from the Energy Commission, which was matched by the University of California, Davis, the CLTC is working closely with industry in a way not possible at national labs. “We are a marriage-maker,” observed Erik Page, Director of Engineering at the lighting center. “These marriages do not happen on their own due to market forces. So, the CTLC creates links between manufacturers, large end-users, and the utilities themselves.”

The lighting center operates a full-scale lighting application laboratory to help spawn the next generation of super-efficient lighting systems. The lighting center is also providing the forum to shape adequate support systems for new lighting technologies. For example, developing a trained workforce well-versed in best practices when it comes to energy efficiency is another CLTC initiative. See http:// cltc.ucdavis.edu / for more information. “There has been little R&D conducted on the fixture side of the lighting equation, so we try to bridge needs,” continued Page. “Although our research and commercialization goals are based on efficiency savings, what makes these products successful in the market are often other attributes, such as lighting quality, controllability, and public safety.”

The goal of the PIER Program’s *Hotel and Institutional Bathroom Lighting Project* was to commercialize two new energy-efficient bathroom lighting technologies: 1) a retrofit motion sensor nightlight (model WN-100, now available from WattStopper: www.wattstopper.com) and 2) a smart vanity light targeting new buildings and renovations (model MBV, now available from Speclight, a subsidiary of Lithonia Lighting: www.speclightsolutions.com). Both of these technologies feature occupancy controls and light-emitting diodes (LEDs) that can reduce bathroom lighting energy use by 50 percent.

The first technology integrates a motion sensor and a low-power LED night light into a standard wall switch (see picture below).

The second one, a vanity light with an LED night-light, features a rechargeable battery with high-performance lamps and ballast in a new fixture, enabling the night light to serve as a safety light during unexpected blackouts. This lighting system can reduce maintenance costs by 33 percent while also improving comfort and safety for guests. The LED light source provides low light that is just enough to act as a guide to the bathroom and even to use in the bathroom without turning on the main lights, preserving night vision for the trip back to bed, encouraging greater sleep comfort and saving energy. This smarter light is also a complete, out-of-the-box system that allows businesses and institutions to avoid the comparatively expensive and time-consuming traditional hotel/nursing home bathroom renovation approach of custom-made fixtures constructed on-site with separately installed controls.

Vanity light with an LED night-light.

All told, the total statewide technical potential for energy savings for both of these fixtures could reach 120 GWh/year.

Better "Downlights" for Residential and Commercial Applications: "Downlights" are relatively inexpensive in-ceiling fixtures with a clean look desired by many building owners and lighting designers.

Kitchen downlights.

But in typical installations, every downlight is handled as an individual fixture, requiring hardwire connections with significant labor costs. Instead of fluorescent lights, inefficient incandescent lights are extensively used in downlights, partially due to the high labor and materials costs for fluorescents, which require separate ballasts for each fixture.

This RD&D effort was to boost the efficiency of downlights for residential and commercial applications, without sacrificing design or aesthetics considerations. Compared to incandescent fixtures, energy savings exceed 50 percent for these compact fluorescent downlights. This project helped identify integrated packages that were flicker-free and provided warmer, high-quality illumination. Additional attractive features include "plug and play" wiring connections, eliminating the need for expensive and time-consuming installation procedures, and the use of a single ballast to power the lamps in two fixtures.

Plug and play wiring connection.

Due to the success of this first-generation (2004) residential product (both are now available from Lithonia), a version of these downlights incorporating the same "master-remote" strategy was developed for the commercial sector. Significant office applications for the commercialized products also evolved over time. The easier installation, elimination of redundant components and the thermally-enhanced ballast configuration of the new "systems thinking" design help these new downlights cut energy use, reduce labor and equipment costs, and ensure a longer lamp life.

2. DARKER-COLORED COOL ROOFS FOR HOMEOWNERS

A long-held homeowner preference for a darker-colored roof is making homes hotter, since a dark roof absorbs more than 90 percent of the sunlight energy striking it. In sunny California, this effect translates into peak roof temperatures ranging from 150° to 190° Fahrenheit (F) on hot summer days and contributes to high demand for electricity for cooling. In contrast, light-colored roofs, which tend to reflect rather than absorb heat, are 50 to 60 degrees cooler on average and can reduce building cooling electricity consumption by up to 40 percent.

Cool roofing materials, which generally create a white-colored roof, have been readily accepted by the commercial sector. In response to an Energy Commission rebate program, for example, many high-profile businesses purchased cool roof products, including such chains as Wal-Mart, Lowe's home improvement stores, Sears, and Target. Cold storage businesses, including SYSCO, Foothill Beverage Company, and Commerce Center Cold Storage, saw the greatest energy savings from cool roofs.

In response to the aesthetic barrier to white-colored cool roof products for homes, the Energy Commission launched an RD&D effort in 2001 to develop a diversity of darker-colored cool roof products—including a cool asphalt shingle, the leading U.S. roofing material—for the residential market. The Energy Commission invested $3.1 million from 2001 to 2006 and enlisted the help of more than 15 manufacturers to develop and bring colored cool roof technology to market. As a result of this research effort, the list of infrared reflective roofing materials available in the marketplace in colors homeowners prefer has increased dramatically.

Forging a Path Toward Darker Cool Roofs

The Colored Cool Roofs Project funded by the Energy Commission, Lawrence Berkeley National Laboratory, and Oakridge National Laboratory involved more than 15 industry partners to develop darker-colored cool roofing products. The project team began by developing highly reflective dark-colored pigments and creating software to design high reflectance coatings that match the colors of conventional roofing products. The team also worked with the manufacturers on the team to develop novel manufacturing methods, which these industry partners used to produce new cool roof products in an array of darker colors. Additionally, field testing and validating the energy savings of the new products by comparing their performance with visually similar traditional roofing materials, often in side-by-side installations, was performed.

The new cool shingles on the right very nearly match the colors of conventional products shown on the left.

Among the new products to emerge from this effort are cool asphalt shingles, introduced by Elk Roofing Technology Center. This project stimulated interest in the development and exploitation of new technologies to reduce residential energy usage. Elk Premium Building Products now offers colored shingles with a reflectivity rating of 25 percent or more. (In comparison, traditional roofing materials reflect from 7 to 18 percent, whereas a white roof may reflect up to 70 percent of sunlight.)

Darker-colored cool roofing shingles on two houses advertised by Elk Roofing, the firm that introduced cool shingles in the United States.

In addition, cool dark-colored coatings for metal roofs—traditionally among the most troublesome roofing options from the perspective of cooling—are now commercially available.

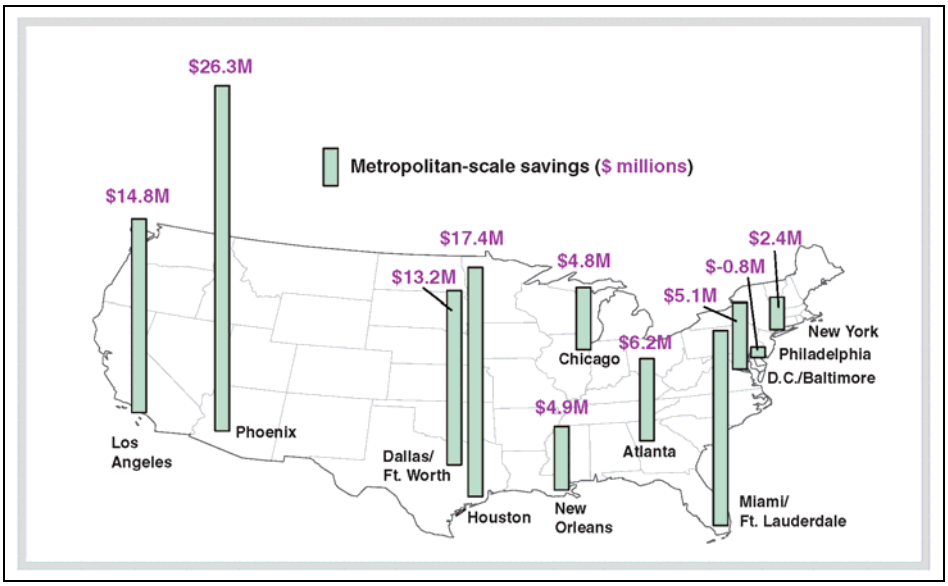
> "Over the past 18 months, the light bulb has come on in our industry. Cool roof technology is spreading across the country. All of our products today now feature cool roof technology."
>
> Tony Chiovare
> President
> Custombilt-Metal Roofing

> "In light of global climate change, promoting cool roof technology to generate energy savings is an excellent public policy."
>
> Yoshi Suzuki
> President and CEO
> MCA Tile

Diverse Benefits of Cool Roofs

According to Berkeley Lab researcher Hashem Akbari, the lead principal investigator for this Energy Commission-funded project, cool roofs offer the opportunity for tremendous energy savings not only in California, but across the nation. "Our research in 1997 showed that the potential net energy savings in the United States achievable by applying white roofs to commercial buildings and cool colored roofs to houses was valued at more than $750 million per year," he said. With today's energy prices, Akbari estimated these savings could "easily surpass $1 billion per year."

Figure 3
Potential Value of Potential Annual Residential Savings from Cool Roofs



The potential value of potential annual residential energy savings from cool roofs in 11 U.S. metropolitan areas is immense.

Beyond this enormous energy efficiency savings, widespread adoption of cool roof technology offers a long list of ancillary benefits. For example, cool roofs reduce the urban heat island effect–a phenomenon caused by large areas of dark surfaces in cityscapes, such as roofs and pavements, that absorb and hold solar energy. Heat islands also can accelerate the rate of smog production through photochemical reactions between pollutants in the air–reactions that increase as temperatures rise.

Cool roofs also prevent excessive swings in roof temperature and corresponding expansion and contraction, in turn, decreasing the tendency of a roof surface to pull away at the seams. By reducing these damaging temperature swings, as well as the deterioration linked to ultraviolet rays on ordinary dark roofing materials, a cool roof not only lasts longer but is less likely to leak.

Finally, cool roofs produce these benefits without adding a cost penalty. According to an analysis performed by the Energy Commission's PIER Program, the initial cool roof installation costs are about the same as traditional roofing alternatives.

In recognition of the energy benefits, both Pacific Gas and Electric (PG&E) and Southern California Edison now have customer incentive programs for residential roofs. The PG&E program provides a rebate of $0.10 per square foot for reflectivity of 25 percent and $0.20 per square foot for reflectivity of 40 percent.

This RD&D project continues to make progress, developing additional roofing products and monitoring the energy impacts. The near-infrared-reflective pigments developed under this project are being applied in other end uses as well, such as automobile coatings, where absorption of heat from the sun also has a significant impact on air conditioning energy use.

State Building Standards Upgraded

To date, California is the only state with a major statewide push to install cool roofs, though light-colored roof materials have been popular in Florida, Georgia, and Arizona. The city of Chicago implemented a cool roof mandate a few years ago.

With support from the manufacturers who participated in the Energy Commission's RD&D efforts to make cool roof technology a commercial reality, a proposal for the 2008 revision of California's Title 24 Building Efficiency Standards has been made to add 25 percent roofing reflectivity to the prescriptive standard for high-slope residential and commercial roofs. This reflectivity level was found to be cost effective in nearly all California climate zones.

California Cool Roof Standards

A “cool roof” for low-sloped buildings must meet these two state standards:

Solar Reflectivity (the percentage of the sun's energy a surface material reflects): A flat cool roof product must demonstrate solar reflectivity of at least 70 percent upon installation.

Thermal Emissivity (the percentage of heat a material can emit away or radiate from itself when compared to a black surface at the identical temperature): A cool roof product must have a thermal emissivity of at least 75 percent.

The Energy Commission is considering cool roof standards for buildings with steep-sloped roofs. Among the proposals under consideration are for the standards to establish the prescriptive energy budget with a roof having thermal emissivity of 75 percent and solar reflectivity of at least 25 percent. Roofs with higher reflectivity would get additional energy credit.

3. NEW TOOLS FOR MANAGING PEAK DEMAND

Traditionally, utilities rely on reserve capacity to meet peak electric loads, such as when thousands of air conditioners are turned on during hot summer afternoons, but with deregulation and growing demand for energy over the past decade, available reserves must now be carefully managed. California utilities can build more peaker power plants to help meet peak loads, but these plants represent large sunk investments that may be used only for a few days or even hours per year. The state can also develop strategies and technologies to reduce peak demand.

Strategies for reducing peak demand include utilities politely asking that their customers turn things down or off when demand is too high for their generation capacity to handle. This can literally be as direct as radio announcements and e-mails asking people to "Flex Their Power^{SM}," and voluntarily turn off excess appliances. Or, it can involve enrolling customers in dynamic rate programs. All of these demand reduction strategies reduce reliance on peak generation and help utilities avoid planned blackouts while also decreasing the likelihood of catastrophic system failures. The decreased need for peaking generation also means less pollution because these plants might be used less or not at all.

The Energy Commission, the California ISO (responsible for operating the transmission system within California), and California utilities are on the cutting edge of demand response research and implementation. For instance, in 2004 the Energy Commission created the Demand Response Research Center (DRRC) at Lawrence Berkeley National Laboratory (LBNL) to research and develop demand response approaches and technologies.

The following projects indicate how the Energy Commission is advancing the state-of-the-art in peak demand reduction tools. The AutoDR project is developing and demonstrating technologies for automating demand responses, and DRBizNet is a software tool that is being developed to streamline the implementation and coordination of all kinds of peak demand reduction programs for utilities and their customers.

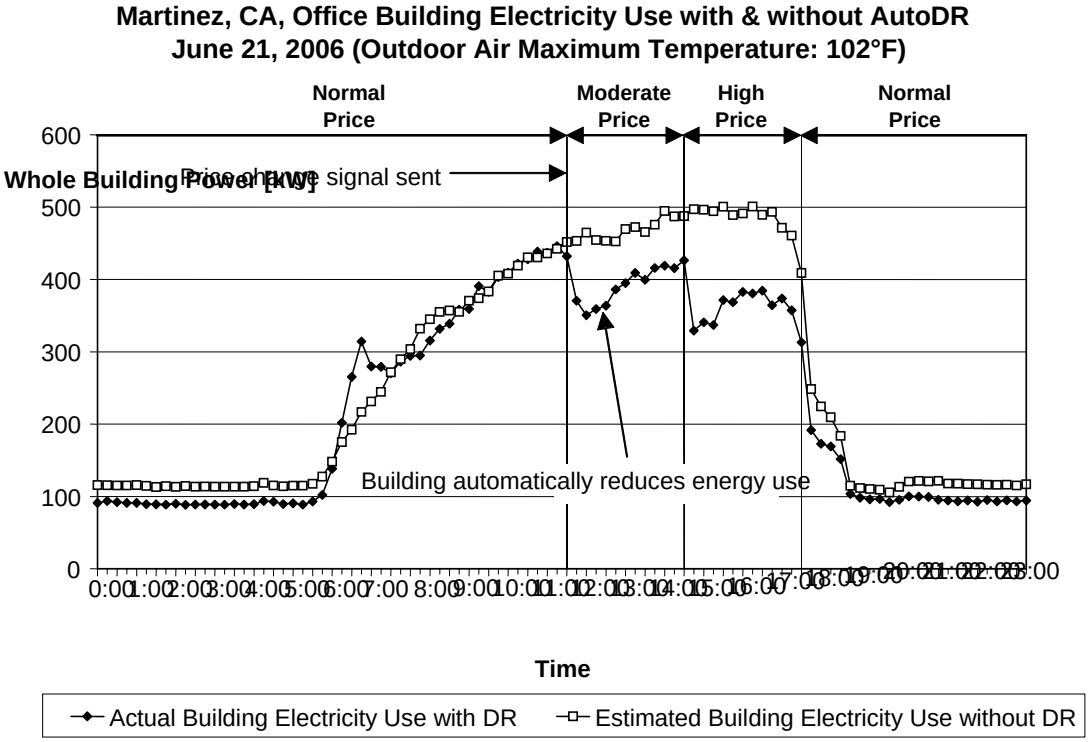
AutoDR: Automating the Response to Peak Loads

The Energy Commission and research teams at Lawrence Berkeley National Laboratory, working with utilities and customers, have developed and field-tested AutoDR technologies in a variety of businesses throughout California. These technologies send secure pricing signals over the Internet to large commercial and industrial facilities (for example, office buildings, schools, museums, data centers, postal facilities, libraries, retail chains, and supermarkets). The businesses in turn use AutoDR technologies to reduce a facility's energy consumption (for example, automatically raising the building's thermostat set-point, or dimming lights) when power prices exceed a pre-programmed price point. This automatic load reduction can be achieved with minimal disruption to building occupants and business operations.

Figure 4
Energy End-Users

Who Are Largest Energy End-Users?

According to the federal Energy Information Administration, commercial buildings account for 35 percent of total electricity demand. On top of that, these same commercial buildings represent 45 percent of summer peak demand, more than any other sector of the economy. The chart below, produced by Lawrence Berkeley National Laboratory shows what happened when AutoDR technology was used at a Martinez, CA, office building to detect and respond to electricity price increases.



The top line shows projected demand on June 21, 2006, reaching nearly 500 kW over a 15-minute interval without AutoDR as outdoor temperatures increased. The bottom line shows the actual impact of AutoDR, dropping demand below 400 kW for most of the afternoon.

The development of AutoDR technologies and programs and their introduction into the electricity market have required and continue to require unprecedented collaboration among large building owners, utilities, and specialized IT service firms, and timely investments from the Energy Commission.

PG&E Pilot Project on Peak Demand Reduction Tests AutoDR: PG&E's Critical Peak Pricing currently operates by informing a human operator of price changes, who must then manually reduce a facility's load. Researchers at the Demand Response Research Center (see sidebar) saw a great opportunity to integrate PG&E's price signal with AutoDR technologies, allowing the automatic reduction of load at test facilities throughout California.

Results from four years of Energy Commission-funded RD&D on AutoDR involving over 40 facilities revealed average demand reductions of about 10-15 percent during the three- to six-hour-long peak demand response events. Representatives from firms as diverse as Albertson's, Target, and Cisco report that they believe automating demand response by price signals can institutionalize these savings, thereby providing California with reliable demand response savings.

"Last year, we consistently reduced our electricity consumption by more than 30 percent with peak power pricing and AutoDR," noted Wayne Wiebe, vice president of Echelon, a San Jose-based control networking technology firm and PG&E customer. "In 2006, we concentrated on energy reduction strategies that would have no impact on our employees, and we still maintained demand reductions near 30 percent. These results have given us the confidence to sign up for PG&E's demand response rate structure in 2007," he said.

Due to the success of the Energy Commission-funded research on AutoDR, PG&E, Southern California Edison, and San Diego Gas & Electric are implementing AutoDR control technologies in their service territories this year. For example, PG&E plans to install AutoDR technologies in 200 large commercial facilities in 2007 to reduce peak demand by 15 MW. Since PG&E has been conducting a pilot automation program since 2005, the utility is convinced the approach is sound and will effectively meet demand reduction targets developed by PG&E, the Energy Commission, and the CPUC.

The Demand Response Research Center

The Energy Commission created the Demand Response Research Center (DRRC) in 2004 with the mission to develop cutting edge solutions to the challenge of meeting ever rising peak demand. The DRRC is designed to serve the multi-institutional needs of the CPUC, the California Independent System Operator, utilities, consumer groups, trade associations, technology vendors, and other research organizations. The DRRC is managed by Lawrence Berkeley National Laboratory (LBNL).

The DRRC has brought different parties to the table to help find the path to market for innovative technologies that conserve instead of create energy. Among other things, research funded by the Energy Commission has evaluated the value of demand response to customers, utilities, and the grid-at-large. The evaluation went beyond pure economic costs, addressing environmental and other societal costs and benefits, too.

By underwriting research and fostering collaboration among LBNL, investor-owned utilities, building managers, and the CPUC, the Energy Commission has helped shape the final AutoDR design to be eligible for state utility financial incentives earmarked for demand-side management programs.

The Energy Commission's 2004 forecasting model estimates that the state's commercial buildings represent a total of 20 gigawatts (GW) of potential energy

demand. It is estimated that employing strategies and technologies such as AutoDR can reduce this massive figure by 15 percent during critical peak periods of demand, saving the equivalent of 3 GW of electricity.

“We are still at the program development stage, examining and looking for ways to improve the critical factors that can make AutoDR a success. But clearly, the potential savings from AutoDR are enormous,” commented PG&E’s Krill.

A Lawrence Berkeley Laboratory Perspective

“There are at least three key findings from our R&D work,” commented Mary Ann Piette, the lead LBNL researcher on Auto DR. “First, many commercial buildings currently have the capability to shed 10 to 15 percent of their peak electric loads for several hours with minimal or no impact on building occupants or tenants. Second, our research shows we can fully automate shifting and shedding peak loads at fairly low costs. And third, building operators and facility managers like the automation and readily accept it as a technique to be used over many years and many demand response events.”

She notes that AutoDR grew out of the Energy Commission’s demand response planning process and was fully funded through its PIER Program during the first two years of technology development. PG&E and San Diego Gas & Electric collaborated with LBNL and the Energy Commission during the field tests in both 2005 and 2006.

DRBizNet: Software to Enhance and Manage Demand Response System

Currently, the processes to operate demand management programs – from upfront customer enrollment to real-time communications, to the final financial settlements – are cumbersome and time-consuming. Some large commercial customers have required weeks or months to enroll in programs. Additionally, signals from the grid operator currently must go through multiple channels and multiple hands – some automated, some not. All these processes have hindered the potential effectiveness of demand management programs statewide.

The *California Demand Response Business Network* (DRBizNet) R&D effort, supported by the Energy Commission and managed by the California Institute of Energy and the Environment (CIEE), provides enabling technology for back-end systems to automate and streamline demand response-related processes. For example, using DRBizNet, California utilities will be able to better manage and optimize their internal business processes related to demand management such as customer enrollment, meter management, and settlement processing.

“The future of our electric power system relies heavily on the use of modern communication technologies,” commented Terry Mohn, a technology specialist and enterprise architect at Sempra. “DRBizNet focused on solving these problems for our industry. We at Sempra (parent company of San Diego Gas & Electric) wish to see this state-funded research move into the mainstream.”

The DRBizNet architecture allows entities such as the California ISO to manage and call upon demand response resources in a coordinated and strategic manner. The architecture provides a framework for systems involved in demand response across the state to communicate in a secure, reliable, and well-defined manner. This capability will allow demand response stakeholders and participants such as California ISO, investor owned utilities, aggregators, and customers to collaborate in real-time. What this means is that once the technology framework is fully developed and tested, the grid operator will be able to transmit load-reduction signals efficiently, flawlessly, and instantaneously to millions of participating customers.

Deploying a real-time demand response network as envisioned with DRBizNet has the potential to boost the benefits of demand response by a factor of 10, at 1/10 the cost of today's uncoordinated system. Furthermore, DRBizNet lays the foundation for a dynamic marketplace for demand response that could ultimately engage the state's 11 million residential customers in demand response activities daily, involving all ratepayers in the effort to maintain electricity system reliability while minimizing costs.

Besides the state's private utilities, several other companies have been involved in this innovative research project, including Utility Integration Solutions, Dynamic Networks, NEXANT, SAVVION, and TIBCO. To date, Energy Commission funds have been used to design and develop the DRBizNet architecture and framework. In 2006, the Energy Commission demonstrated DRBizNet in a field simulation with participation from the California ISO and the three California investor-owned utilities.

DRBizNet's goal is a unified, flexible, and open architecture featuring "plug-and-play" services that protect investments in demand response and that lower costs for all stakeholders. The next phase for DRBizNet may involve a statewide pilot of the technology, or DRBizNet may go straight into commercialization. In either case, the technology will find a path to the market and set the stage for the nation's most sophisticated demand response network.

4. ENHANCING TRANSMISSION CAPABILITIES

The electric transmission grid delivers power from generators to distribution grids. California's transmission grid was designed for reliability at a minimum cost. This was during a time when grid managers had access to generator operating parameters and could coordinate power generation and manage power quality concerns manually, over the phone, with a limited number of utility system operators.

Deregulation has created a dynamic situation for which the transmission system was not designed. Generation is now deregulated and not coordinated, resulting in fluctuations on the grid and decreased reliability. Some renewable resources add power to the grid at unexpected times, causing power management issues. To maintain grid reliability under these deregulated, uncoordinated conditions, the California ISO conservatively constrains the amount of power on the grid to maintain an acceptable margin of error. This conservatism results in unused transmission and generation capacity.

Growth in electricity demand, especially peak demand, has placed additional stresses on California's transmission system. Until additional transmission segments are built, it is imperative that existing transmission lines be able to be used to their full capacities to ensure delivery of sufficient power during peak demand periods, without exceeding those capacities. For example, excessive heating and sag of a utility transmission line were the cause of the major power outage that hit California and the western United States in August 1996.

The Energy Commission created the Transmission Research Program (TRP) in 2003 to enhance the capabilities of California's transmission grid to deliver environmentally sound, safe, reliable, and affordable electric power from generators to consumers. The projects highlighted in this section address better measurement and management of power lines to maximize their capacities, and better frequency management of the transmission system using flywheel storage to enable the integration of renewables.

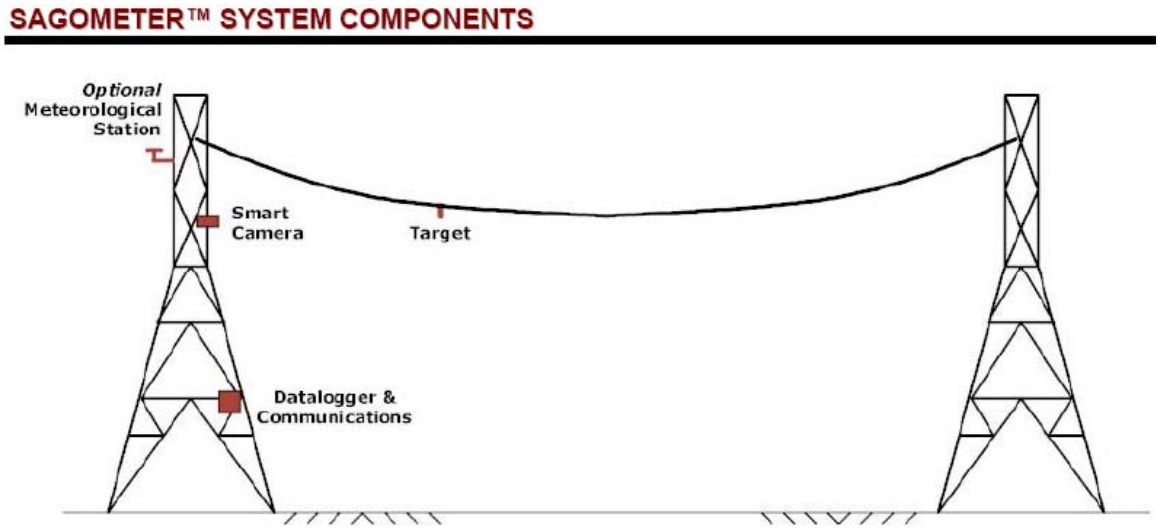
Increasing Transmission Line Capacity: As the amount of power moving through a transmission line increases, the line heats up. As the line gets hotter, the wires expand, and the transmission line sags. To prevent sagging lines from becoming a public safety hazard, transmission lines are assigned a static power rating. This rating is based on very conservative assumptions about weather conditions that affect sag. As a result, the static rating limits a line's transmission capacity even when actual weather conditions would allow the static rating to be exceeded safely.

Two Energy Commission projects are addressing the issue of transmission line sag. The first project uses sensors to provide real-time data on the ground clearance of power lines. This data can be used to safely increase a line's capacity when weather permits. The system, developed by Engineering Data Management (EDM) International and The Valley Group, was proposed under

the Real-Time Dynamics Monitoring System (RTDMS) initiative and has been field tested by California utilities.

The projects succeeded in developing a “sagometer” based on sensors mounted on a tower. It allows monitoring of the sag of the line in real-time. Software was developed to
display the results.

Figure 5



In operation, a utility can collect data from numerous monitors placed on its system and process and send the information to the California ISO – the entity responsible for operating the majority of the state’s high-voltage wholesale power grid. With this information, the California ISO can designate a dynamic capacity limit to allow greater amounts of power to pass through the lines safely. EDM estimates use of this system can result in a 2 to 5 percent increase in the overall transmission system power transfer capacity, a 20-30 percent increase in useful capacity for lines with specific ground clearance limitations, and 15-25 percent reduction in the need for acquisition of transmission rights-of-way.

Reducing Transmission Line Sag: The Sagging Line Mitigator

While the Energy Commission often works with utilities and large firms as partners, the state energy RD&D Program also reaches out to smaller entrepreneurs. Take, for instance, the story of the Sagging Line Mitigator or SLiM, developed by Power Transmission Solutions (PTS):

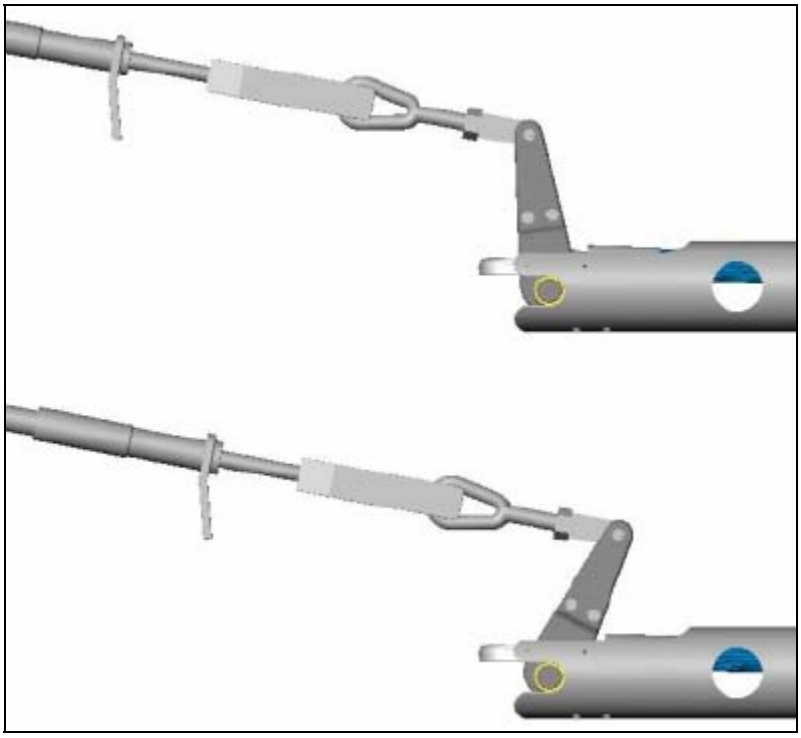
SLiM is designed to address the problem of transmission line sag directly. Relying upon state-of-the-art material science, SLiM keeps lines from sagging by physically stretching the lines more as they heat up. SLiM is a low-cost technology that can increase electricity throughput and improve public safety at the same time.

Testing on a San Diego Gas & Electric 69-kilovolt line yielded impressive results. “We feel SLiM holds great promise for giving us the opportunity to increase the amount of power we can move over the lines without the environmental or visual impact of re-conductoring or putting in new poles,” said SDG&E spokeswoman Stephanie Donovan. The SLiM device could also be a very cost-effective solution that “benefits not only us, but our customers as well,” she added.

SLiM is now a commercial product, and the Energy Commission received its first royalty payment from sales in the spring of 2006. To date, PTS has sold SLiM devices to the European utility ESKOM and is negotiating with two other European utilities. Recent changes in federal law governing transmission have removed incentives for SLiM domestically, but PTS hopes that as its performance is tracked in Europe, increased sales in the United States will eventually follow.

“Commercialization remains a challenge, but we remain convinced that SLiM will play a significant role in preventing fires and improving the reliability and power transfer capabilities of California’s transmission system.”

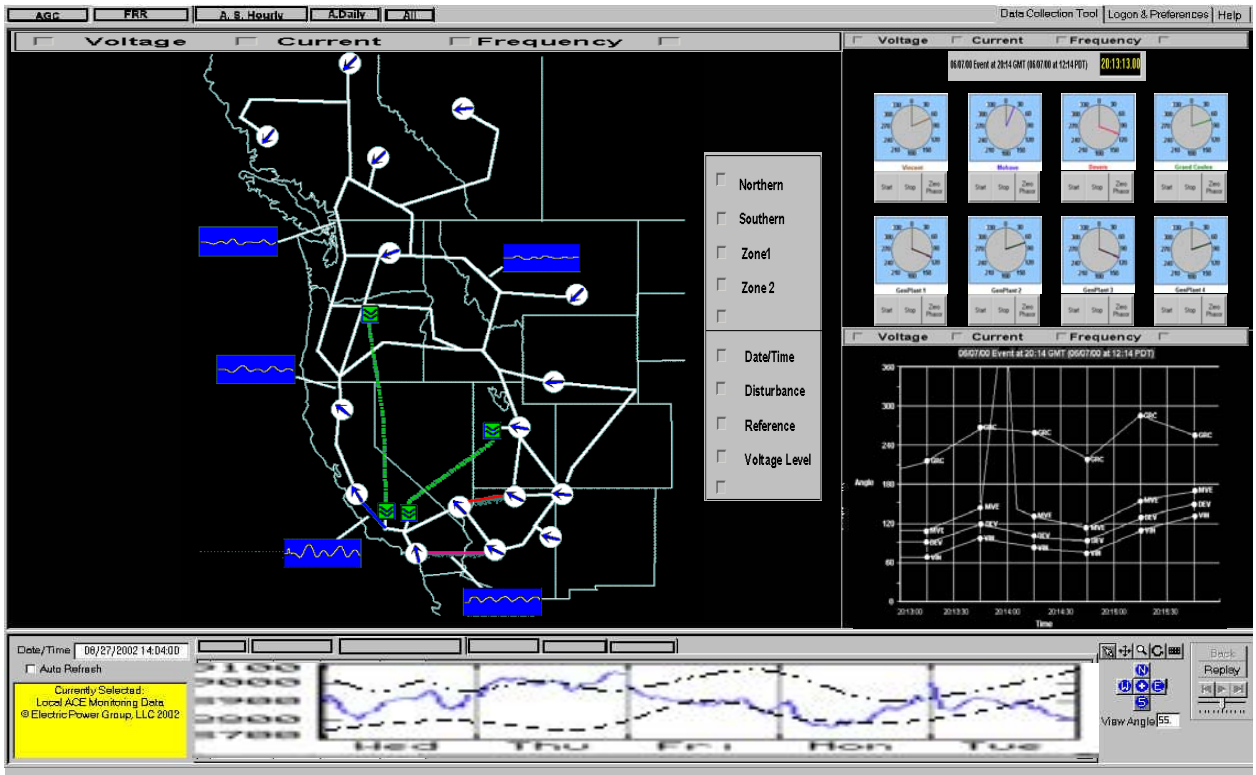
Manuchehr Shirmohamadi
Chairman
Power Transmission Solutions



SLiM in action. As the temperature increases, the SLiM actuates and pulls the transmission line more tautly (bottom picture), decreasing line sag.

Another RTDMS innovation focused on accessing unused transmission capacity is the “phasor measurements tools” project. Sensors have been installed to measure and display the real-time status of transmission at various locations around the transmission grid. These tools are like the temperature gauge on a car dashboard, providing grid operators an early warning about possible problems with the transmission grid. Phasor measurements allow California ISO to keep track of an ever-changing, dynamic grid and to safely tap into unused capacity. Phasor measurements can also be used to observe stresses on the grid over a wide geographic area caused by generators going off and on-line.

Figure 6
Real-time Phasor-Based Monitoring and Alarming Display



Real-time Phasor-Based Monitoring and Alarming Display

The arrows on the map represent the phase angle measurements. A sudden or unexpected change in the angle direction (arrow direction) indicates something new is happening on the grid that may require action.

The phasor toolbox system is already providing dividends to the state transmission system, even though it is still under development. David Hawkins, California ISO's Industry Relations Representative, reported that on the morning of April 19, 2006, a California ISO reliability coordinator used the information provided by the prototype phasor measurement tool to flag a serious voltage problem on the system. The operator resolved this voltage problem by dropping two hydroelectric generators at Helms Pumps, thereby averting a potential grid emergency.

Frequency Stability with Flywheel Energy Storage Systems: Frequency stability of the transmission grid is something that affects equipment ranging from household electric clocks to huge industrial motors. Disruption and even damage can result if the frequency of the electric power is not held constant at 60 Hertz (cycles per second). To maintain a consistent frequency on the transmission grid, the California ISO has to continually ask power plant operators to make small adjustments to their generation output. Since generators work best when

operating at a steady output, this process is inefficient, increases wear and tear on the generators, and increases their pollution.

A new flywheel energy storage system, developed by Beacon Power of Wilmington, Massachusetts, with funding from the Energy Commission, can provide the same service more efficiently without burning fossil fuel. Beacon's system works by spinning a carbon-fiber composite flywheel at a very high speed to store electricity in the form of kinetic energy.

The beauty of this technology is that it can respond almost instantaneously to frequency excursions. Whereas it takes conventional power plants up to five minutes to respond to California ISO signals, the flywheel storage energy system takes only four seconds to respond, greatly improving the frequency regulation of the transmission network.

This project is an excellent example of how the Energy Commission through the PIER Program has helped bring to market an innovative technology developed by a smaller firm. In addition to the Energy Commission's investments, the U.S. Department of Energy (DOE) and the New York State Energy Research and Development Authority (NYSERDA) have subsequently contributed to the development of this exciting technology.

5. MAXIMIZING RATEPAYER VALUE WITH NEW RENEWABLE RESOURCES

To assist system planners and operators, as well as to meet new state policy goals, research funded by the Energy Commission has produced a set of state-of-the-art methodologies and tools to strategically direct placement of new renewable energy supplies to improve the reliability of the state power supplies. The simulation tools and analysis methodologies were designed specifically to comply with the state's RPS, which requires that 20 percent of the state's electricity supply be derived from renewable resources by 2010.

Called *Strategic Value Analysis* (SVA), the methodology is designed to maximize the value of ratepayer investment in new renewable resources. The SVA quantifies how the addition of renewable energy projects can improve transmission reliability in California. No other state government has addressed, on a statewide basis, the linkage between increasing renewable supply and increasing the reliability of the transmission and distribution system at the same time.

SVA takes a systems view of how the transmission grid interacts with an optimal, cost-effective mix of new renewable resource options. The approach itself is noteworthy in that it integrates the values of various renewable energy fuels and technologies at specific locations. The values are then quantified based on a calculation of their net impacts on the transmission grid.

The SVA approach can also be used to quantify "non-energy" benefits such as economic development or climate change mitigation, leaving the door open to further refinements of complete life cycle and fully internalized costs of energy as well as future market services. The approach provides a level playing field to assess costs and grid benefits of all new renewables developed in California according to the state's aggressive RPS targets. SVA has evolved into a platform of tools being employed to strategically locate new electricity resources throughout California's transmission system.

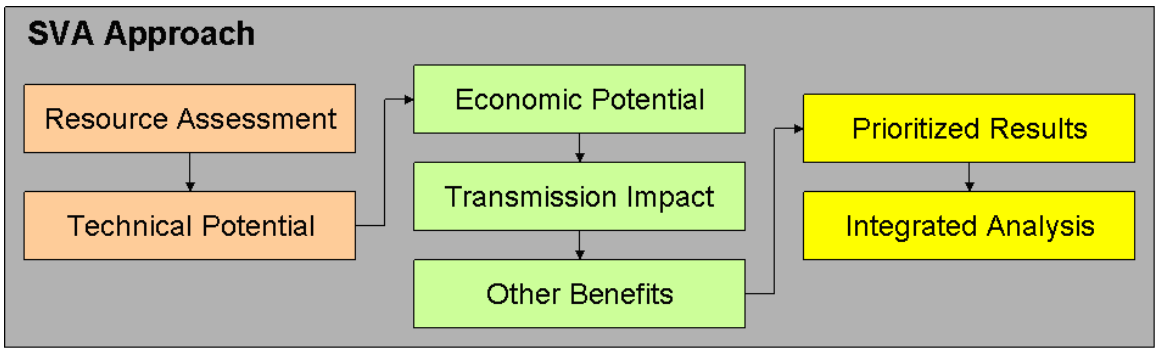
The Why and How of SVA

California's electricity transmission system has become increasingly stressed in recent years. One of the reasons is that changes in the power market increasingly require the use of the transmission system in ways for which it was not designed. California's utilities need to invest right now in new supply capacity to maintain reliability while enhancing the power market in an environmentally acceptable way. Requirements to add new renewable resources according to the RPS complicate matters but also offer promising opportunities to shield ratepayers from fuel price volatility, to reduce greenhouse gas emissions, and to enjoy a variety of other non-energy benefits. Ultimately, the benefits from the increased use of renewable resources must be balanced with the environmental impacts and costs of new transmission facilities required to connect and deliver them.

This is the SVA methodology in a nutshell: First, SVA analyzes the power flows through the existing transmission system and locates potential transmission problem areas. Then, by overlaying the best renewable energy resource locations over the transmission system using a geographic information system (GIS) tool, sites are identified where renewable technologies provide a benefit to the system by reducing transmission line congestion.

Partnering with the California Department of Forestry, the Energy Commission completed a resource assessment for each of the renewable technologies. From the resource assessment, they developed gross technical and economic potentials for each renewable resource. A detailed analysis screened for the location of transmission "hot spots" or transmission congestion areas, resulting in an overlay map that displayed the transmission hot spots and the economic potential of each renewable technology at those geographic locations.

Figure 7
Step-by-Step SVA Approach



The economic feasibility of newly deployed renewable resources (wind, geothermal, solar, and biomass) was evaluated by comparing "levelized cost of electricity" (LCOE) values for state-of-the-art renewable technologies against current market price estimates. (The LCOE is an estimate of the true long-term energy costs from each technology, factoring in capital and fuel costs and other relevant considerations.) Only those renewable projects deemed cost effective and market-ready when compared to conventional fossil generators were carried to the next round of analysis.

Since there are transmission lines of different sizes and in different utility control areas, a methodology was developed that compares the transmission benefits of locating different generators at different locations systemwide on an unbiased basis and without considering utility boundaries. Potential impacts of deploying new renewable generation along with conventional fossil generators on the state's electricity system were assessed using two new transmission reliability index metrics developed by the Energy Commission's PIER Program with outside consultants. Relying upon these two metrics, a corresponding value known as a "transmission impact ratio" is derived to compare the value of one generator over another to maximize transmission benefits.

A series of resource and transmission model simulations identified specific renewable energy projects at strategic locations whose value to the overall system was greater than the numerical value of their capacity. This previously unrecognized “extra” value is due to resulting improvements in the performance of the overall transmission grid, particularly at specific “hot spots” of congestion where supply is constrained by lack of transmission availability.

Projected Ideal Mix of Renewable Resources

SVA found that 85 percent of the state’s current RPS goal for 2010 can be met with new in-state renewable energy resources that require minimal or no additional transmission upgrades. Furthermore, if strategically located, these new wind, geothermal, solar, and biomass generators can help to improve grid reliability by avoiding congestion. The strategic placement of these new renewable generators could also help bring to market new low-wind speed, solar, distributed biomass, and other distributed generation (DG) technologies.

Among the significant findings in the 2010 RPS scenario are the following:

- The largest amount of new capacity additions would come from new wind power projects totaling 3,041 MW, a figure representing 51 percent of new capacity developed during the 2010 time frame. Geothermal capacity would total 1,214 MW or 20 percent of the total new capacity.

- For peaking power needs, concentrating solar power technology installations (1,046 MW) were more than double the amount of new residential solar photovoltaic (PV) systems (500 MW) installed. These two solar technologies represent 17 percent and 8 percent, respectively, of the new RPS supply.

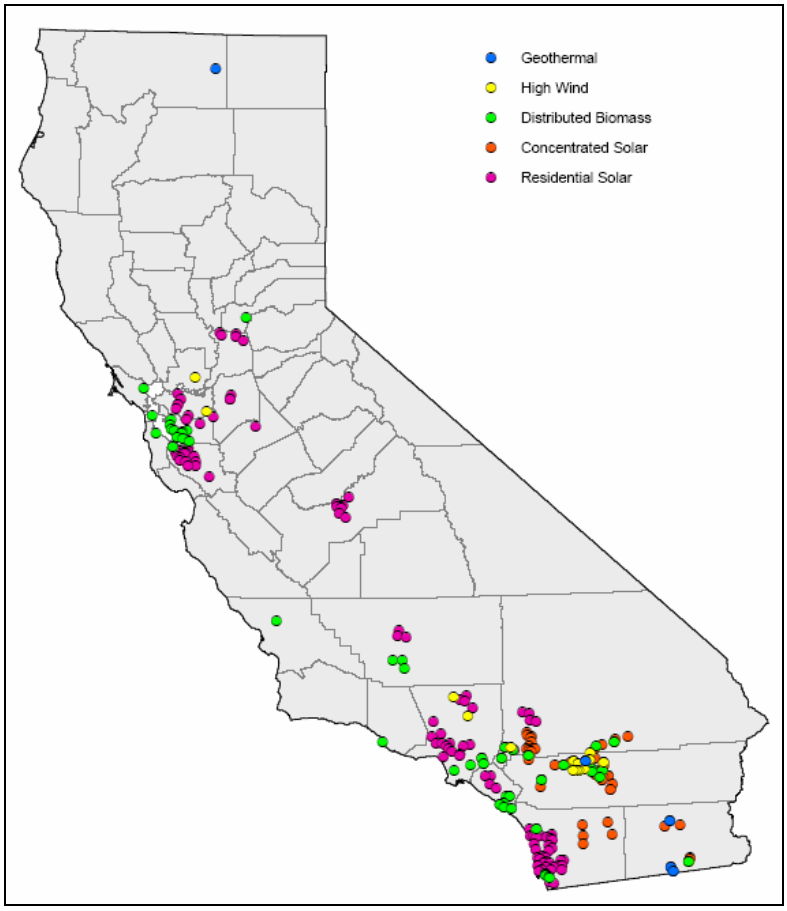
- It should be noted that the scenarios developed under SVA were completed before the adoption of the $3 billion California Solar Initiative (CSI) solar PV program. A follow-up project has analyzed scenarios that meet the anticipated solar PV penetration targets. The SVA 2010 scenario was also completed before focusing on developing 3,000 MW of new wind supply capacity in the Tehachapi wind resource area. Later work at PIER incorporated the transmission studies necessary to support this proposed Tehachapi wind power development goal.

- Biomass facilities (dairy manure, wastewater, and landfill gas) round out the new RPS portfolio at 228 MW or 7 percent of the RPS supply.

- Emerging ocean/wave energy and other small hydro technologies were not assessed under SVA due to lack of technology maturity and excessive costs.

The California map below shows the general locations of the 6,029 MW of renewable resources added under the SVA scenario in 2010 to meet the 20 percent RPS target.

Figure 8
Approximate Locations of New Renewable Generators Per
2010 SVA Integrated Results



Integrating renewable resources based on a SVA approach to meet the RPS would bring immense benefits to California that go beyond the provision of electricity supply. Carbon dioxide (CO_2) emissions linked to global climate change are the dominant form of pollution avoided by switching to renewables instead of fossil fuel electricity resources. The economic value of projected air emission reductions (including all state criteria air pollutants) exceed the economic value of tax receipts associated with deployment of new renewable energy generators by more than three times. By 2010, annual benefits are projected to be $425 million; by 2017, an additional $165 million in benefits are realized. Approximately 42,000 jobs are projected to be created by 2017 under the SVA RPS scenarios examined, with about 6,200 of these jobs representing full-time operating personnel.

Moving Beyond SVA

As the utilities and developers move forward in complying with RPS purchase requirements, SVA and subsequent methodologies could foster a consensus process to determine the “best value” renewable energy resources from a systems perspective. If used as a transparent analysis tool for all market participants, SVA and related methodologies could showcase California’s RPS implementation as a trendsetting platform for the rest of the country.

The Intermittency Analysis Project (IAP) and a number of regional studies have leveraged and refined the data originally developed under the SVA. The IAP, which looks at how the intermittency of renewable resources such as wind and solar power will affect transmission operations as penetration levels increase, incorporated transmission metrics and tools developed under the SVA.

The California ISO, which manages the majority of the state’s transmission services (including utilities such as PG&E), is very interested in the nexus between renewable energy sources and transmission solutions. ChiFong Thomas, a PG&E principal consulting engineer, commented, “The SVA is a screening tool for estimating potential locations, amounts, and timing of renewable resources. The resulting sets of ‘prioritized’ renewable resources then provide reasonable portfolios to serve as data points for further detailed evaluation of the transmission upgrades needed.”

PG&E will be leading research for the Energy Commission funded-Northern California Regional Integration of Renewables project (RIR), which takes a big-picture look at a variety of renewable resources and how they best fit into the greater Northern California and PG&E’s service territory. For that project, utilities will also be developing longer-term planning scenarios that integrate a diverse renewable portfolio and other power plants to supply electricity in Northern California through 2020 and beyond. The goal of this utility-led research is to complement existing statewide transmission integration activities as well as benefit from collaborations with all other members of the Western Electricity Coordinating Council (WECC) – an organization dedicated to ensuring grid reliability throughout the West – and other regional and state study groups.

Recommendations for Further Research

SVA provides a consistent and transparent process to aid resource planning for all generating resources (renewable and conventional) by calculating a *transmission impact ratio*. This ratio methodology -- or similar grid benefit assessment – could be incorporated into the state RPS procurement process.

Projected transmission impacts and estimated renewable energy supply costs should be updated with actual utility project data and then tracked to further improve the methodology.

To conduct a statewide transmission analysis, the SVA relied on various Energy Commission offices (transmission siting, electricity supply) as well as utilities to compile a common database. To refine this analysis, a common dataset should be available to coordinate renewable assessments for resource planning, transmission planning, and energy policy needs.

SVA needs to be expanded to include seasonal transmission power flows. Many transmission problems could occur during the non-summer peak periods.

Because SVA provides a prioritized list of new renewable resources based on “least-cost, best-fit” evaluation criteria, it can be easily integrated into utility transmission planning, resource planning, and bid processes. SVA can allocate renewable resources within each utility service area based on systemwide transmission reliability impacts.

6. WIND POWER IMPROVEMENTS

Over the past decade, wind power has been one of the fastest growing electricity resources in the world. Long a wind-industry leader, California is poised to regain the national lead in total installed wind power capacity that was only lost to Texas in 2006. The passage of the RPS, which requires California to supply 20 percent of the state's total electricity from renewable resources by 2010, has accelerated implementation of wind energy in California. Since wind power is the lowest cost renewable power generation option currently available, it is projected that as much as 12,000 MW of additional wind capacity may come on-line in response to the RPS legislation.

The Energy Commission is addressing issues surrounding transmission scheduling and planning to deal with the increase of wind generation on the California grid system. Because of the inherent variability of wind turbine output, careful coordination must be exercised so it is integrated smoothly with existing generation sources. The Energy Commission has funded a project to improve transmission planning policies and forecasting of wind system output so that wind power can be more efficiently integrated into the California grid system.

The Energy Commission is working with a wind turbine manufacturer to develop a unique drivetrain – the hardware connecting the rotor to the generator – that distributes and reduces stress on turbine components as turbine rotor blades continue to increase in size. Additional RD&D helped that same manufacturer develop a wind turbine with the ability to harness energy in lower-speed wind regimes that is able to operate over a wider geographic area.

Wind Forecasting for the California ISO: The California ISO was among the new regulatory institutions created by the state's 1996 energy restructuring law taking over management and control of the transmission grids for the state's investor-owned utilities. The California ISO schedules energy production from generators in advance to match generation with forecasted consumer electricity demand. Due to unpredicted outages there are always some deviations in power scheduling, and generators of electricity are subject to fees based on their deviation from energy delivery schedules.

The California ISO fee system has been a major barrier for wind generators. Wind power production frequently deviates from schedules due to the inherent variability in the wind itself. The net deviation between scheduled and delivered energy triggers high penalties for wind projects, making them less attractive from a resource scheduling point-of-view. Since the ratepayer ultimately pays these costs, maintaining this arrangement is obviously not in the public interest.

Energy Commission funding helped establish a partnership among the wind industry, wind forecasters, and the California ISO that solved this problem. With the industry and state agencies, the California ISO created and implemented a new program that addressed a key market barrier to increased reliance upon wind power, without new subsidies. It simply re-works protocols and payment

schemes used by grid operators geared to the operating characteristics of round-the-clock fossil fuel power plants.

It was not easy arriving at an integrated program that addressed both the financial needs of a wind power industry struggling to adjust to a deregulated system of scheduling and the real-time pressures of California ISO grid operators to secure power deliveries to keep the lights on 24/7. But a consensus process involving market participants and governmental agency stakeholders came up with a novel approach that helped satisfy everyone at the table. Indeed, this consensus process developed such an innovative compensation and availability forecasting system for wind power projects that the Federal Energy Regulatory Commission (FERC) and other grid operators have investigated adopting it for their own use.

Energy Commission RD&D Addresses these California ISO Wind Energy Concerns

- Helping to better forecast generation from wind projects in a region on a day-ahead and hour-ahead basis.

- Helping to affordably integrate wind projects into the California ISO transmission control area without having to purchase significant amounts of power from other generators to fill gaps when the wind is not blowing.

- Helping the California ISO better accommodate California's wind resources, where wind projects do not always generate electricity when there is significant demand and sometimes generate when demand is low.

- Helping accommodate new renewable resource development. As significant wind resources come on line as envisioned under the RPS, the variability of wind may cause problems along critical transmission pathways. What planning is required to provide sufficient transmission?

- Giving California ISO schedulers better tools and more flexible options to manage and dispatch wind power, since wind-generated electricity is a "must take" resource in California.

- Members of Independent Energy Producers, American Wind Energy Association, California Wind Energy Association, and wind energy marketers were all brought into the same room with representatives of the Governor's Office, CPUC, California Energy Commission, and the California ISO. One of the top goals in this consensus process was to be able to forecast wind energy production far enough in advance to avoid starting expensive and polluting peaking fossil units.

The California ISO's Participating Intermittent Resources Program evolved from the Energy Commission-funded research involving the Electric Power Research Institute, federal national laboratories, and AWS Truewind, a wind power technical consulting firm. This latter firm helped California ISO adopt a

sophisticated wind forecasting service that instead of focusing on what the wind did the last hour or last ten minutes, relies upon a weather and terrain analysis to provide forecasts for the hour ahead. Each individual wind project participating in this California ISO program is required to install meters, share in the costs of forecasting, and schedule energy deliveries based on new state-of-the-art predictions of energy production.

On the financial side of the equation, participating wind generators are exempt from certain categories of penalties. Deviations due to wind variability are handled in the same way as changes in consumer demands for power. Rather than netting scheduled energy deliveries on a 10-minute basis – the California ISO's standard procedure – wind facility participants net differences hourly. A monthly settlement process then nets deviations from forecasts across all hourly time intervals at the weighted average electricity price for the month.

California ISO is currently working with the Energy Commission to further refine and improve the state's wind forecasting capability and to better integrate short-term hour-ahead wind forecasts with the transmission pathway schedulers. The ability of the California ISO grid operators to balance the grid will only get better as data is collected month-to-month and year-to-year for existing and new wind projects serving the California power market. As more wind projects participate in the California ISO program, the benefits to California ratepayers will grow, due to the increased geographic diversity of wind projects, each with its quantified hourly, daily, and seasonal electricity generation profiles. New advances in wind forecasting technologies and market-based reforms will give the California ISO the ability to better understand and manage wind power that best fits into California's power supply portfolio.

> "Accurate forecasts and schedules for wind generation energy production is an essential for capturing the value of renewable resources. If we can accurately predict how much energy will be produced by wind generators, we can then ramp down energy production from fossil fueled generators or even schedule them to be shut down and off-line. This saves money and reduces greenhouse gases. Accurate forecasts also help the grid operators anticipate what the wind generators will do ahead of time, and they can more reliably operate the system."
>
> Dave Hawkins
> Lead Industry Relations Representative
> California Independent System Operator

Clipper Wind's Distributed Generation PowerTrain: The scale of wind turbines has grown significantly since first-generation machines were installed in California in the early 1980s. While utility-scale wind turbines started out in the 25- to 50-kilowatt range, multi-megawatt turbines such as Santa Barbara-based Clipper Wind's 2.5-MW Liberty wind turbine are now being installed. These large wind turbines feature spinning rotor blades as large as two jumbo jets standing side-by-side.

Perhaps the most noticeable drawback to the scale-up trend was powertrain structural failures, which began to reduce wind facility power production as turbines producing at 1 MW or more went offline, sometimes for lengthy repairs. The huge blades of contemporary wind turbines place tremendous stress on drivetrains, yet the design of these powertrains had not been optimized in response to the increased structural stress.

Through several PIER-funded RD&D efforts, Clipper Wind investigated a radically different powertrain design. Dubbed a “distributed generator” drivetrain, it integrated eight different generators into a single powertrain to spread the intense torque along the rotor shaft to multiple generators instead of just one large piece of hardware. By distributing the stress across multiple pathways, Clipper Wind discovered a solution that could greatly reduce the downtime of large multi-megawatt wind turbines.

This innovation, among others funded by the Energy Commission and the U.S. Department of Energy, also served as the basis for Clipper Wind turbine designs that can harness the kinetic energy from lower speed winds, opening up new wind development opportunities over a broader area of the state and nation. By being able to operate at lower wind speeds, these wind turbines can be installed closer to urban centers with high demands for electricity, reducing investments in transmission infrastructure. Clipper Wind is developing a family of Liberty wind turbines that can efficiently operate at low wind speeds. This holds particular promise for California as it looks to develop additional renewable energy supplies from lower-speed wind resources regimes.

With continued development Clipper Wind ultimately simplified its distributed generation powertrain, reducing the number of generators from eight to four. Now labeled “Quantum Drive,” the latest iteration features a two-stage helical distributed powertrain design.

When Clipper Wind received its first grant from the Energy Commission’s PIER Program in 2000 to develop a test prototype of the distributed drivetrain, the firm was small, though composed of industry veterans such as CEO James Dehlsen, whose original wind power company Zond was purchased by Enron and later by General Electric. Clipper Wind received subsequent PIER RD&D funds to develop and test a full-scale powertrain on a wind turbine at the National Wind Technology Center test site in Boulder, Colorado. Clipper Wind’s success in developing more sophisticated and durable wind turbines is evidenced by its successful initial public offering (IPO) of stock in the fall of 2005.

7. FOSTERING INDUSTRY USE OF EFFICIENT TECHNOLOGIES

California's vast industrial, agriculture, and water (IAW) sectors—vital to the state's economy—are large energy users, accounting for 30 percent of the electricity consumed annually in the state. Working with these sectors to improve the energy efficiency of their processes has therefore been a priority at the Energy Commission.

Often, advanced new technologies are available that can provide the sought-after energy saving. However, concerned about costs, impacts on other process systems, and effects on product quality, industry can be slow to adopt even the most promising new technologies if they lack a confirmed track record. In many cases, the Energy Commission works to establish impartial data on the economics, energy savings, and process, and quality impacts of new technologies can be key to fostering acceptance—thereby accelerating potential energy benefits to the state.

The year 2006 saw the culmination of two Energy Commission projects to develop unbiased data on technologies with enormous potential for IAW stakeholders. The first project confirmed the energy and other benefits of electrodialysis filtration, an emerging technology for stabilizing wine. The second demonstrated the energy savings and economics of a gas-fired hot water heat pump for food and beverage processes. As discussed below, results from wine demonstrations have proven influential in shifting a hesitant market toward acceptance, while the economic benefits proven in the gas-fired heat pump demonstration promises to spur strong industry interest.

Confirming the Benefits of STARS for Wineries

Winemakers worldwide go to great lengths to prevent the formation of tartrate crystal sediments in wine—normal and harmless by-products of winemaking that are nonetheless disconcerting to consumers. The most common prevention method, cold stabilization, calls for chilling the wine in refrigerated stainless steel tanks for two to three weeks before bottling. Unfortunately, cold stabilization is one of the most energy intensive of all winery processes, consuming about 75–300 kW/1000 gallons of wine treated.

A search for an energy-saving alternative by a French research institute in the 1990s led to the selective tartrate removal system (STARS). Consuming only 11–15 kW/100 gallon, STARS uses electrodialysis to pass minute layers of wine between two sheets of membranes for selective removal of tartrates and related sediments (see sidebar for details). Though STARS is accepted and used by wineries in Europe, American wineries were reluctant to adopt the new process without home-turf validation of its benefits—and confirmation that it would have no harmful effects on wine quality.

Recognizing the potential benefits of the new technology to California's large wine industry, the Energy Commission sponsored a project to test STARS at

wineries in the state, working with the Napa-based company Winesecrets. Winesecrets built a mobile STARS demonstration unit capable of processing 600 gallons per hour and documented its energy saving characteristics and performance at four leading California wineries.

How Does It Work?

The purpose behind cold stabilization is to remove all tartrate crystals from a wine during its fermentation stage. They are a natural product of the wine and form when the wine gets too cold. It is in essence cream of tartar forming because of the temperature change. If you think of sugar turning into rock candy, you'll have a good mental image.

Tartaric acid is a normal grape acid. Potassium also exists in grapes, and when these two things bind together under chilly conditions, they form little potassium bitartrate crystals, which then settle to the bottom of the bottle. They are completely harmless and quite natural, but consumers often do not understand their appearance in wine.

Europeans accept these crystals as a sign that the wine is a natural one, and even appreciate their presence. Americans are used to wine being clear, pure, filtered, processed, and de-sedimented. If consumers see little crystals in their chardonnay they often think they are impurities or even bits of broken glass. Cold stabilization is a way to prevent product returns.

Tests of more than 1 million gallons of wine showed that STARS can save between 80 to 90 percent of the electricity used in cold stabilization. Adopted statewide, these savings could total 24 million kWh of electricity a year. Equally important, the tests allowed wineries to compare the quality of STARS-treated wine to wine produced with cold stabilization. Although a few wineries preferred wine undergoing cold stabilization, the majority found no significant quality difference between wines treated by the two methods. The tests also showed that STARS reduced product losses compared to cold stabilization and allowed wineries to speed their time to market by eliminating the two-week chill.

In fact, these tests were so successful that they convinced the U.S. Alcohol and Tobacco Tax and Trade Bureau to issue approval letters for adopting the use of this new technology—eliminating a major barrier to wider industry use.

And the future of STARS looks bright, as use by industry leaders grows. For example, Fetzer Vineyards, one of the project test sites, has rented a STARS unit for several years and is metering energy savings with PG&E. Domaine Chandon started using STARS in 2005 for chardonnay and for the base wines used in its sparkling wine. Further, Tom Tibuerzi, a sparkling winemaker, plans to purchase an 800-gallon-per-hour unit for 2007. Finally, Winesecrets, which received a 2006 *Flex Your Power*^{sm} award for its mobile STARS treatment

service, processed more than 1 million gallons in 2006, saving its clients $130,000 on their energy bills.

Mobile STARS treatment service. Commissioner Art Rosenfeld learns about STARS technology.

Proving the Value of the ThermoSorber™ Gas-Fired Hot Water Heat Pump
The many food and beverage industries that require both heating and cooling for processes typically rely on gas-fired boilers to supply the heat and electric refrigeration systems to provide cooling. Naturally, reducing the energy use and costs of these systems is a major concern.

One solution may be the ThermoSorber™ gas-fired hot water heat pump, recently developed by Energy Concepts Company with the support of the Department of Energy. Improving on the proven heat pump technology, ThermoSorber™ produces hot and cold water by pumping heat from a lower temperature to a higher temperature (see sidebar for details). Requiring just a fraction of the energy consumed by conventional heating and chilling, ThermoSorber™ has enormous potential. However, the food and beverage industry's limited familiarity with the technology was a significant barrier to its adoption.

How Does It Work?

A steam-driven ammonia absorption cycle is key to ThermoSorber™ operation. The unit pumps a solution of ammonia and water to high pressure and heats the solution to produce ammonia gas. That gas is then condensed and expanded to low pressure to generate cooling. Subsequent absorption returns the ammonia gas to its previous state as a low-pressure solution, allowing the cycle to continue. The heat rejected in the condenser and the absorber provides the heating effect.

The Energy Commission hoped to overcome this barrier by installing and monitoring a 10-ton ThermoSorber™ unit at a processing plant in Modesto operated by the Squab Producers of California. Over the six-month test period, the unit showed significant energy savings—68 percent savings in electricity and almost 28 percent savings in thermal energy—compared to conventional heating and chilling technology.

A second, larger demonstration was installed and began testing a 100-ton unit heat pump at a Central California poultry processing plant in January 2006. This plant, run by a major poultry producer, requires a continuous flow of at least 190 gallons per minute hot water and 190 gallons per minute chilled water to process 50,000 birds per hour for 15 hours each day.

The steam-powered ThermoSorber™ chills 110 gallons per minute and heats 120 gallons per minute, operating 21 hours a day, 5 days a week. According to the demonstration, the 100-ton unit should cut the plant's annual energy bill of $520,000 by about $110,000. With a capital cost of $180,000, the cost benefits are clear: the ThermoSorber™ unit at this plant should pay for itself in less than two years.

On the basis of these demonstrations, California utilities are actively considering providing rebates for the ThermoSorber™, which has potential application throughout industrial and commercial facilities that need both hot and chilled water. Currently PG&E is exploring the use of this technology for hospitals that have a high need for both heating and cooling simultaneously.

> **"**This project demonstrated that the savings with the ThermoSorber™ are large and the economics very favorable. This is the type of technology that merits high priority, given the world's urgent need to stem fossil fuel consumption and reduce greenhouse gas emissions."
>
> Donald Erickson
> President
> Energy Concepts Company

8. TRANSFORMING WASTES INTO CLEAN ENERGY

The annual production of municipal solid waste (MSW) in the United States has more than doubled since 1960. When waste is placed in a landfill, microbes decompose the organic matter, and a gas composed primarily of methane, a potent greenhouse gas, is released. Nationally, only 25 percent of this potential fuel is captured and combusted for electricity generation. Likewise, wastewater streams from food processing can contain significant energy resources that are in many cases “wasted” by being released to the atmosphere or released to be processed in wastewater treatment facilities. It is clearly in the public interest to develop technologies that reduce these greenhouse gas releases into the atmosphere, especially since methane is 20 times more damaging to the climate than carbon dioxide, the focus of most climate change response programs. It is also in the public interest to develop these waste streams into alternatives to fossil fuel electricity generation.

The Energy Commission through the PIER Program has identified and demonstrated two promising technologies that can derive clean electricity and reduce the volume of waste from municipal landfills and agriculture and food processing wastewater streams. Both of these RD&D projects fall under the broad category of “biomass,” a term that refers to a diverse group of fuel feedstocks derived from organic matter, whether wood or agricultural solid wastes, gases, or water wastes derived from municipal waste management systems.

Tapping these waste streams and converting them into electricity supports California’s efforts to reduce greenhouse gas emissions, as expressed in SB 1250 and AB 32, the Global Warming Solutions Act. In addition, using these wastes helps achieve the Governor’s Executive Order S-06-06 and the subsequent Bioenergy Action Plan. This research is also valuable in the state and federal governments’ efforts to manage the nation’s solid and liquid waste streams in a more efficient and sustainable manner.

The first project profiled – a landfill bioreactor – could help California produce clean, renewable electricity from landfills by speeding up the natural decomposition processes and accelerating fuel availability. The landfill bioreactor project also received funding from the California Integrated Waste Management Board since this process decreases the volume of the waste and so reduces the need for new landfills.

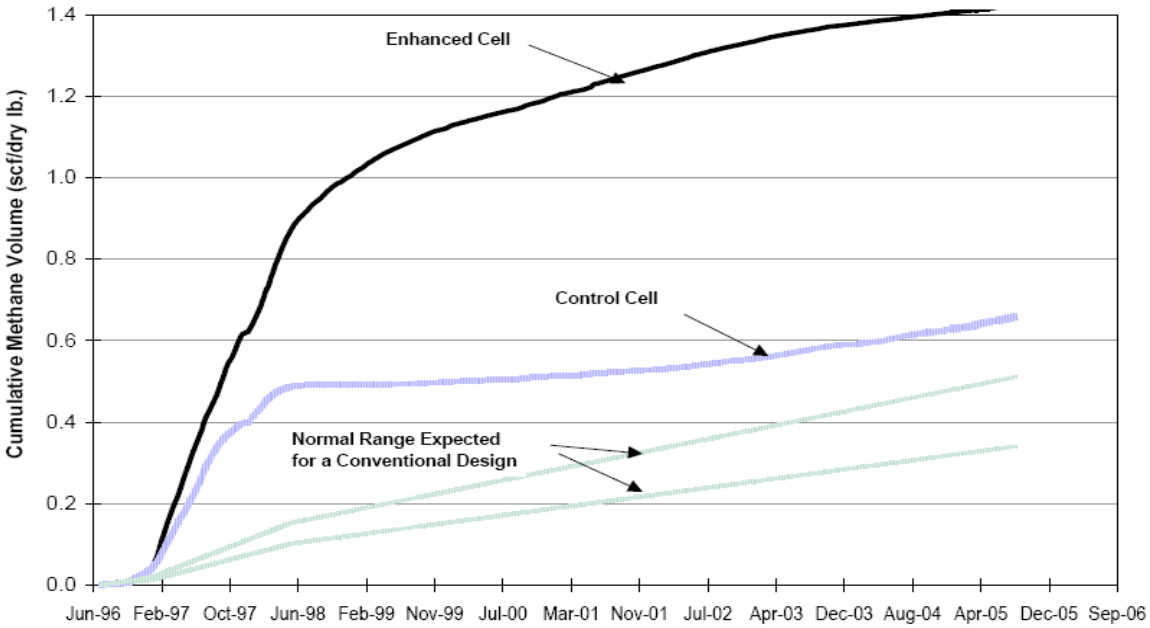
The second project treats a wastewater stream by way of an ancient anaerobic digester technology. Liquid wastes are transformed into gaseous fuels, and the volume and concentration of the waste stream are reduced. The gas is used to generate on-site electricity and provide heat for the digester and the food processing plant.

Both projects demonstrate waste-to-energy biomass technologies with wide-ranging applications, helping California comply with state energy, solid waste, and greenhouse gas reduction policy goals.

Landfill Bioreactor: A primary technical barrier to widespread reliance upon landfill gas as a fuel has been the slow rate of natural decomposition in standard landfills, limiting the size of electricity generators and the corresponding economic feasibility. An Energy Commission grant helped Yolo County investigate an accelerated anaerobic composting process that creates a *landfill bioreactor*. By accelerating methane production in an environmentally sound manner, generating electricity from landfill gas becomes more cost-effective and emerges as a key climate change response technology.

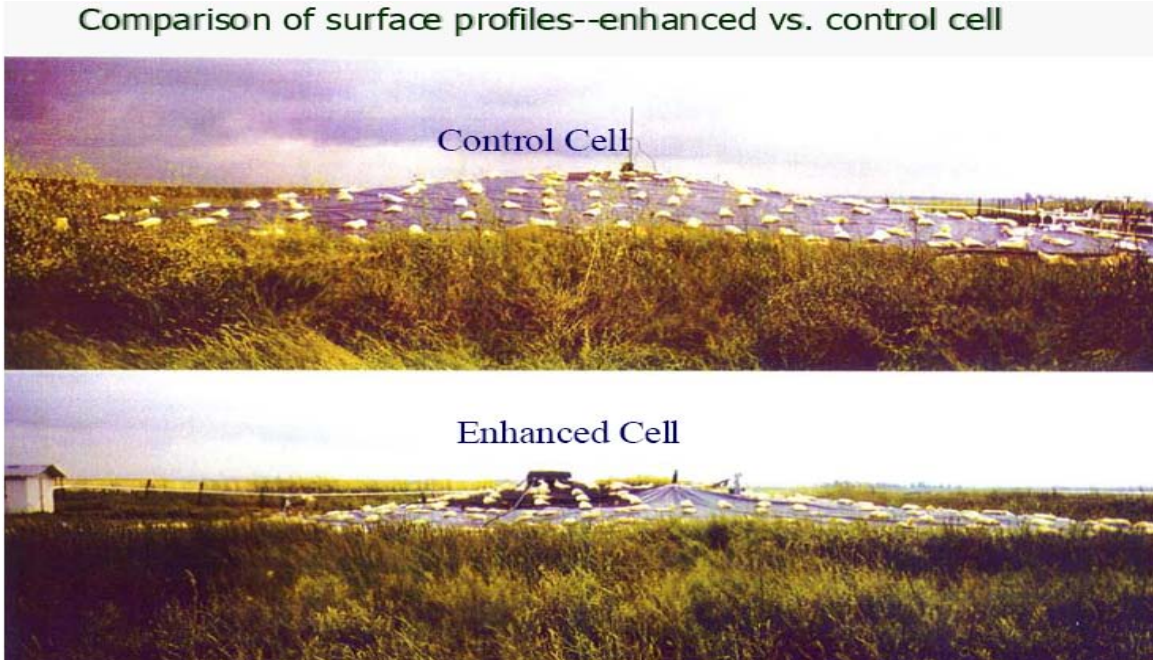
Interest in bioreactor technology dates back to the 1970s, but the technology has, for the most part, been relegated to lab research with few large-scale demonstration projects. In this project, controlled quantities of liquid were added and re-circulated to increase the moisture content of solid wastes located at a full-scale 9.5-acre landfill bioreactor cell in Yolo County. The landfill bioreactor process speeds up the biodegradation rate of the waste, dramatically reducing the amount of time for wastes to decompose and generate methane gas. Instead of 30 to 50 years or more at a conventional landfill, this bioreactor is projected to deliver its fuel over a period of 5 to 10 years. It also offers the opportunity for making these landfills truly renewable resources by managing them for long-term methane production. The full-scale bioreactor landfill at Yolo County is expected to produce more than 57,000 megawatt-hours of electricity, equivalent to about 90,000 barrels of oil, over the expected 10-year life of this landfill.

Figure 9
Cumulated Methane Recovery of Pilot-scale 9,000-ton Enhanced Bioreactor and Control



Note the greatly accelerated methane recovery from the enhanced pilot cell relative to conventional and controls.

After the initial small-scale demonstration, Yolo County determined the economics and benefits of this improved landfill bioreactor technology. While the study proved favorable, regulatory obstacles loomed. Ironically, current federal Environmental Protection Agency (EPA) regulations preclude adding moisture in landfills, which retards – instead of accelerates – gas development. Landfills therefore require long-term monitoring, with its attendant costs, and the risk of a breach leading to a major release of greenhouse gas emissions is increased. Yolo County received funding from the Energy Commission's PIER Program to address the federal EPA regulatory hurdles standing in the way of landfill bioreactor technologies and make the technology more affordable.



Surface profiles of the two 9,000-ton pilot cells operated 1995 to present. Note the waste volume loss indicated by the subsidence of the methane-enhanced cell. This subsidence is due to the destruction of organic waste solids (like paper fractions and food) to form landfill gas.

Promising Bioreactor Study Findings

Bioreactors can provide greater energy benefits than conventional landfill approaches.

Enhancement of methane production is manageable and controllable.

A four-fold increase in the methane recovery rate was demonstrated compared with conventional operation. The data indicate as much as a seven-fold recovery rate increase is possible.

Efficient capture of the generated methane is commercially possible. Tests showed average surface emissions to be under 2 percent of the allowable federal

standard of 500 parts per million. In many cases, the landfill surface methane emissions were undetectable.

This project developed data needed to establish environmental and renewable energy benefits to facilitate regulatory acceptance at federal and state levels.

Capital and operating costs have been documented. From a purely economic standpoint, commercialization is very attractive. Public acceptance is developing, but long-term performance still remains to be verified.

Bioreactor landfills can help California meet its RPS goals by increasing methane gas production for faster and more efficient energy recovery, resulting in a reduced dependency on non-renewable fossil energy sources. Another environmental benefit is less leachate is discharged to the local wastewater treatment plant. Yolo County benefits from reduced long-term environmental liability, a reduction in post-closure care and maintenance costs, and a lengthening of landfill life expectancy.

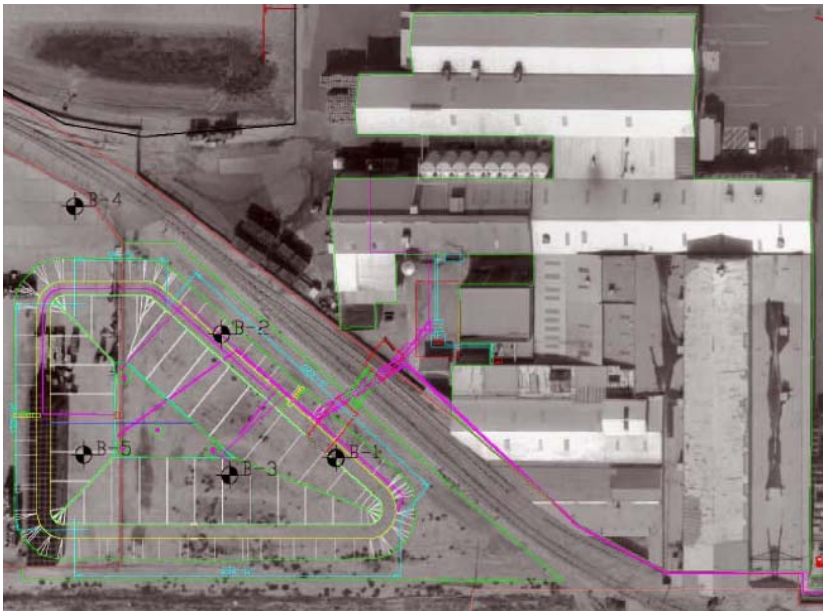
Ramin Yazdani, project manager for Yolo County, has continued to investigate ways to make the landfill bioreactor even more efficient. Typical landfill gas collection systems capture 70 to 80 percent of the landfill gas. Yolo County has experimented with both synthetic and bio-covers in efforts to capture more of this landfill gas.

Along with this work, the Energy Commission is also funding research at the same Yolo County landfill to shift and increase landfill gas collection during times of peak electricity demand. By shifting gas capture and electricity generation to times of peak demand, the landfill can increase its revenue by supplying power when its value is at a premium. “Relying upon a permeable layer may allow us to store gas temporarily, perhaps shifting 10 to 20 percent of our landfill gas for use during electricity peaks,” noted Yazdani. Yet another change he envisions on the horizon is automating bioreactor systems to further reduce costs and improve efficiency.

Valley Fig Growers: For Valley Fig Growers, high wastewater volume has been an ongoing issue. Due to population growth in the city of Fresno, sewer rates are increasing 18 percent in 2007, another 18 percent in 2008, and 21 percent in 2009. To avoid extremely high municipal wastewater discharge costs, the company applied for an Energy Commission grant to build an anaerobic digester system. The system that resulted reduces the concentration of organic materials in their waste, reduces the volume of solid waste that must be hauled away, reduces emissions of greenhouse gases, and produces a significant amount of useful energy in the form of electricity and heat for the company, all from a waste stream.

Primitive anaerobic digesters – essentially covered lagoons – were in existence centuries ago in ancient China for composting of waste, yet the technology still lacks technical maturity in the United States. Although California is the largest

agricultural state in the nation, the food processing industry has few anaerobic digesters in commercial operation. With PIER Program funding, a 0.6-acre digester was built at Valley Fig Growers to convert the sugars washed off figs into methane gas. The effluent from the digester has a greatly reduced concentration of organic material, making it more suitable for processing at the municipal sewage treatment plant.



Digester Site Next to Fig Processing Plant in Fresno, CA

Digester Lagoon Dug, Lined, and Ready for Fig Waste

Digester Lagoon Covered and Generating Gas from Fig Waste

The organic biogas produced by the system was used to fuel a 70-kilowatt electrical generator manufactured by Ingersoll Rand. Resembling a jet engine, and about the size of two refrigerators, this micro-turbine generates a substantial portion of the electricity requirements for the entire facility. The exhaust heat from the generator is also suitable for water heating and other uses.

The two-year demonstration project yielded impressive results. Valley Fig Growers generated two-thirds of its own electricity supply from previously discharged wastewater that was converted into biogas in the digester. Fifty to 100 percent of the waste heat from the micro-turbine was recycled to the anaerobic digester itself to heat process water and to power a dehydrator. The concentration of organic materials in the effluent from the digester was reduced 70-80 percent from the input material, reducing the demands on the local sewage treatment system and providing a benefit to both the local municipality and to Valley Fig Growers. Finally, solid wastes shipped off-site were reduced by 50 percent, from two to one truckload per day. All in all, the company trimmed $100,000 from its annual waste management costs.

“With expected increases in utility rates, the payback on these sorts of dual digester and on-site electricity generation systems will only be quicker,” said Mike Emigh, president of Valley Fig Growers. He added that use of this digester freed up sewer service for the equivalent of 2,500 homes. The purpose of this RD&D project was to show food processors what they can do with their wastewater,” he continued. “We’ve had quite a parade (of other processors) passing through (to observe the results of the project).”

9. DEVELOPING ULTRA-CLEAN FOSSIL FUEL GENERATION SYSTEMS

Generating electricity is responsible for 20 percent of California's greenhouse gas emissions and significant quantities of air pollutants, particularly nitrogen oxides (NOx). Renewable energy technologies such as solar and wind power are extremely clean and emit no carbon into the atmosphere but can offer only variable generate power when the sun shines or the wind blows.

California would benefit from highly efficient, exceptionally clean, low-carbon/no-carbon power generation systems technologies that can operate around-the-clock, be located near end users, and/or that can be started quickly during sudden peaks in demand, when electricity is the most expensive and air quality is most threatened. With these systems, California can have cleaner air, use less natural gas, and help slow global warming.

The Energy Commission has supported a number of companies and technology development projects over the past decade, working to generate cleaner, more efficient electricity from fossil fuels. For example, the Energy Commission is supporting development of an advanced zero emission fossil fuel power plant. This zero emission system could be ideal for utilities or large manufacturing plants or for utilities seeking to reduce their carbon footprints.

A family of Energy Commission-supported projects seeks to reduce the emissions from gas turbines so that they can meet stringent California regulations and be located near large electricity consumers, such as corporate facilities or university campuses. There are important benefits when generation systems are used in this way for "distributed generation":

- In addition to generating electricity, heat in the gas turbine exhaust can be captured and used for industrial processes, or to heat or cool (yes, cool!) buildings. Used in this way, the gas turbine is part of a combined heat and power (CHP) system (also called a cogeneration system). This is very efficient because the hot exhaust may contain half of the energy that was in the fuel. The alternative would be to buy electricity generated at a power plant, where the heat in the exhaust may be wasted, and then buy additional natural gas and burn it for heating or cooling at the user's site.

- When electricity is generated at a central power plant, it needs to go through the wires of the transmission and distribution system to reach the end user. This wastes about 7 percent of the energy. But when electricity is generated at the user's site, this loss is avoided.

- The high efficiency and avoided power line losses of CHP systems mean that less natural gas is consumed and less greenhouse gas is emitted.

- Distributed generation systems can provide the end-user with energy security, reliability, and high quality power for special industrial applications.

Stringent new California air quality regulations require distributed generation systems to be as clean as large power plants. Energy Commission-funded research is helping to ensure that CHP systems can meet these challenging standards so that the benefits of CHP can be realized.

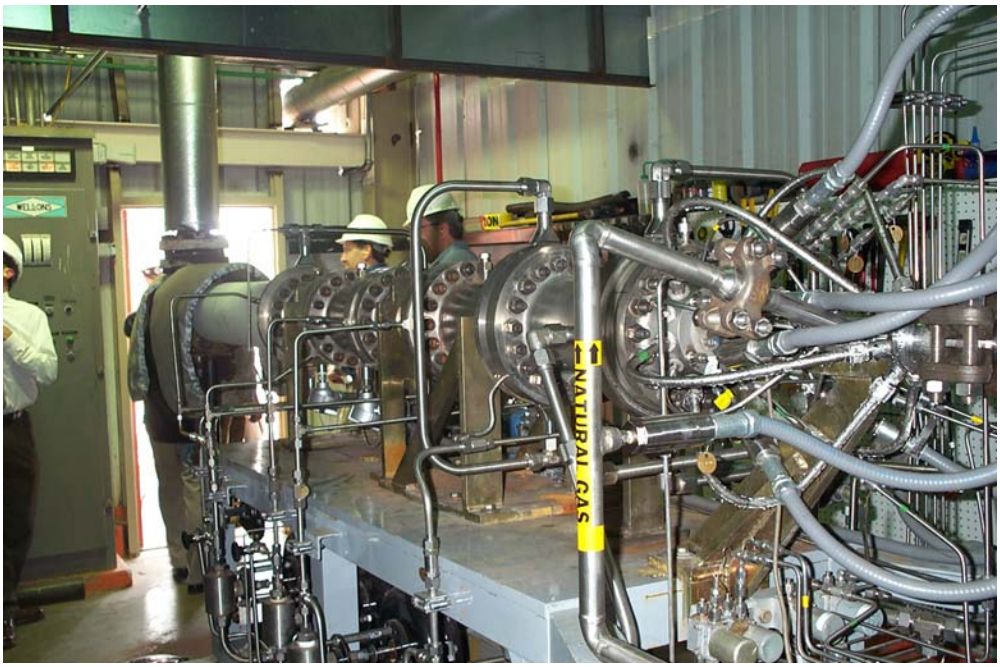
- This “gas generator” technology, as well as a family of other clean-fossil technologies, supports state energy goals of increasing the role environmentally sound power generation technologies play in meeting California’s electricity supply needs. These technologies can potentially provide California industries and other large consumers with zero-emission generators that are carbon neutral and comply with or supersede California’s stringent state air quality standards.

- Development of these and other complex technologies involves a variety of partners, technologies, and end users from the private and public sectors.

Zero-Emission Fossil Fuel Power Plant: Clean Energy Systems, Inc. (CES), of Rancho Cordova, California, has developed an ultra-clean combustion system – a “gas generator” based on rocket engine designs – that burn a gaseous and liquid fuel in pure oxygen, rather than air.

The firm responsible for this was founded by a group of rocket engine engineers (yes, this really is rocket science!) and scientists – many from the NASA space program – who decided in the mid-1990s to address the issues of global climate change. They pooled their expertise to adapt rocket propulsion technology to a pollution-free power plant. “Rockets use oxy-combustion to achieve instantaneous power,” noted Keith Pronske, president and CEO of Clean Energy Systems, Inc. (CES), referring to the process of burning fuel in pure oxygen instead of in air. “The same combustion process can also make zero-emission electricity.”

CES received its initial RD&D funding from the Energy Commission Energy Innovations Small Grant program in 1999 to demonstrate a 110-kilowatt gas generator prototype. The federal Department of Energy (DOE) subsequently provided co-funding to design, build, and test a commercial scale 20-megawatt (MW) gas generator capable of producing 10 MW of electricity and an equal amount of heat energy. The Energy Commission then provided $4 million in co-funding to demonstrate the long-term reliability and durability of a 5-MW grid-connected system at the Kimberlina power plant near Bakersfield, California. The plant successfully exports power to the grid and has accumulated 1,500 hours of operating time with hundreds of starts and stops. It proved to be easy to start, reliable, and easily controlled. Because it can start up so quickly, this technology can also offer services – known as “spinning reserves” – to meet rapid increases in demand on the electricity grid.



The CES 20-MW gas generator installed at the Kimberlina demonstration power plant. Tubes at the right deliver gaseous fuel, oxygen, and water to the injector face. Combustion occurs at the right end of the barrel, with cooling water injected at each bolt ring. The steam/CO_2 drive gas exits to the left, then turns up to power the steam turbo-generator on the floor above.

To understand the complexity of the development path for this technology, consider the subsequent private and public RD&D investors.

AEP, an international power plant builder/operator subsidiary of the Ohio-based American Electric Power utility, acquired CES stock in exchange for the Kimberlina power plant. DOE then provided $14.5 million to Siemens, another international power company, to develop a high temperature turbine to optimize performance of the CES system. Paxton Corporation, a Canadian oil and gas producer, also invested in CES and ordered a 50-MW gas generator. And Southern California Gas Company purchased CES stock in 2006 and announced in January 2007 it was seeking DOE funding to build the nation's first "zero-emissions power plant" in Southern California. Under this proposed project, to be developed in conjunction with CES, the CO_2 exhaust would be permanently sequestered and used for enhanced oil recovery.

How Can a Fossil Fuel Power Plant Have *Zero* Emissions?

The concept of a fossil-fueled “zero-emissions, climate-neutral power plant” may seem counterintuitive, but here is how this configuration works.

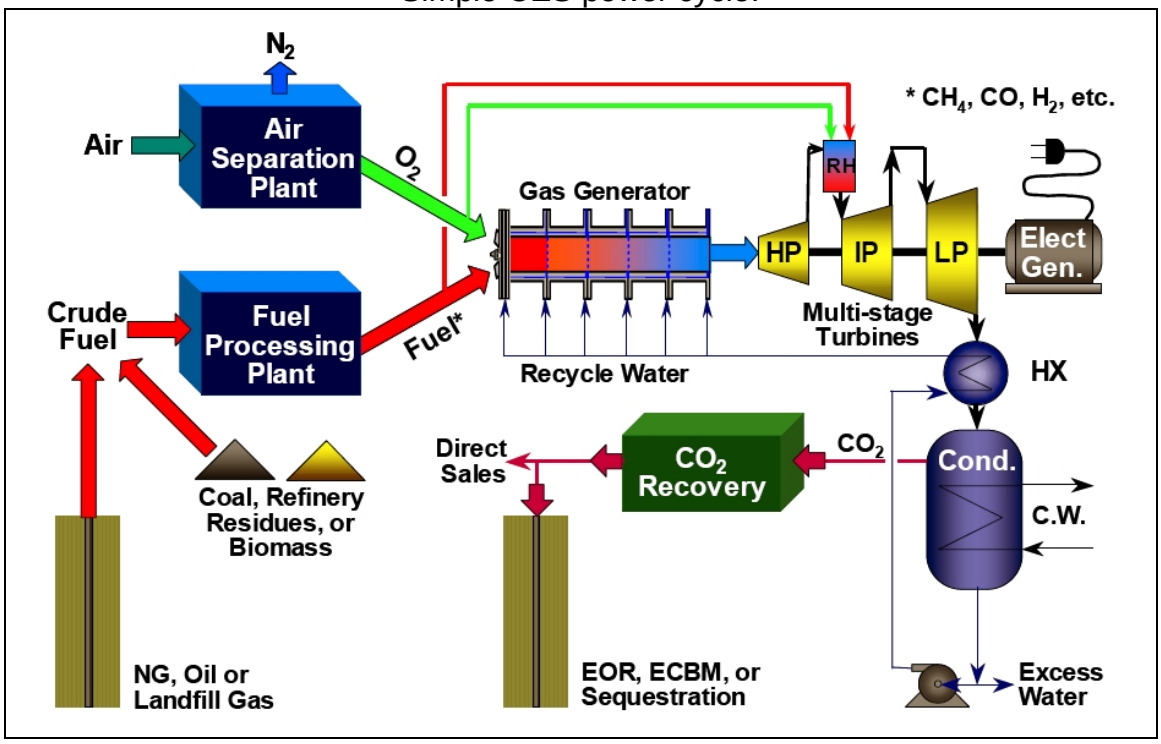
Since no nitrogen is present when natural gas is combusted in the gas generator, no nitrogen oxides (NOx) are created. (NOx is a major contributor to urban smog.) The resulting drive gas, which is composed of nearly pure steam and carbon dioxide (CO_2), powers a steam turbine and generator. The steam is condensed and recycled through the system for cooling. The CO_2, a greenhouse gas, can be sequestered (see Highlight: *Assessing Climate Risks and State Policy Responses*) or sold for commercial use.

For conventional power plants it is not cost-effective to remove CO_2 from the other exhaust gases, but for the CES system, CO_2 is virtually the only exhaust, so it can be captured economically.

Interestingly enough, one commercial application for the captured CO_2 is enhanced oil recovery. If pumped underground, the CO_2 loosens deposits of oil, which then can be recovered economically. By allowing for the economic recovery of more domestic oil supplies from existing sites, the sequestration process could lessen U.S. dependence on imported supplies oil. Up to 5 billion barrels of oil could be extracted under California alone with this technology, according to some estimates.

Alternatively, the CES system can be used in a “peaker” power plant, which might run only a couple hundred hours a year to meet short-term spikes in demand. In this case the gas generator exhaust would be vented into the atmosphere. But with the CES technology, emissions of criteria pollutants, such as NOx, sulfur dioxide, and volatile organic gases, would be significantly less than is achieved with California’s stringent Best Available Control Technology (BACT) standards – without using emissions controls.

Figure 10
Simple CES power cycle.



This figure shows the combustion of a gaseous and liquid fuels with oxygen in the Gas Generator; the drive gas (steam and CO_2) powering a turbine and generator to produce electricity; condensation and recycling of the steam; and recovery of the CO_2 for sequestration, enhanced oil recovery (EOR) or enhanced coal bed methane (ECBM) recovery.

Ultra-Clean Industrial Gas Turbines: Natural gas has become the fossil fuel of choice for electricity generation in California. However, natural gas-fired power plants still emit measurable quantities of NOx, the top concern of most California air quality management districts. Strict air quality regulations in California require additional cleanup equipment.

The traditional pollution control technology for power plants that burn natural gas is called selective catalytic reduction (SCR), but SCR systems are large, and this approach is expensive. SCR systems also carry an environmental footprint of their own, since the ammonia used in clean-up becomes a pollutant if spilled or vented into the atmosphere. Is there a way to change the fuel combustion process so that less NOx is produced in the first place? Is there a way to prevent NOx formation in the gas turbine such that the SCR system is no longer required?

San Diego-based Solar Turbines Incorporated, a part of Caterpillar Inc., is a major manufacturer of industrial gas turbines for electricity generation. The company has been selling small and medium-sized electricity generators (1 to 15 MW) internationally since the 1950s. At present, the company is evaluating and testing a variety of low NOx combustion systems in joint projects with vendor organizations. The goal is to find the best path to a commercial gas turbine

combustion system that will be market-competitive, provide ultra low emissions, and maintain the excellent durability record of industrial gas turbines.

The Energy Commission is helping this California company develop a technology that will comply with the uniquely strict emissions regulations of California, specifically designed to adapt to the state's new air quality regulations, the most stringent in the world. The end result will be that this California firm will offer a clean power generation technology ideally suited to California's unique needs and high standards.

> "Certainly, California is leading the way on air quality regulations and will be the major beneficiary of this work. However, we know that other parts of the United States – such as the Northeast and Texas – will also have near-term needs for this ultra-clean fossil fuel technology."
>
> Ken Smith
> Manager
> Advanced Combustion Solar Turbines

Gas turbines are very complex devices that require significant RD&D to bring this clean combustion technology to market. Solar Turbine's testing has been rigorous, sometimes requiring repeated hardware modifications and retesting in sophisticated test chambers.

When the RD&D at Solar Turbines began, there were three emissions control technologies identified as candidates for the Taurus 70, a 7.5-MW industrial gas turbine frequently used for on-site electricity generation at industrial facilities. The technology providers were Catalytica Energy Systems, Alzeta, which had independently received PIER Program co-funding, and Precision Combustion, which had received DOE co-funding. The Catalytica system provided exceptionally low emissions but was eliminated from the competition because of cost and a change in Catalytica's business focus and because Solar Turbines determined that it was a poor fit with its gas turbine designs. In addition, Solar Turbines began working with scientists at Lawrence Berkeley National Laboratory (LBNL) on a new approach developed at that laboratory with DOE funding.

Under the current contract with the Energy Commission, Solar Turbines is working with the three technology providers to develop production prototype combustion systems including: 1) Alzeta's surface stabilized flame burner, which has received previous developmental funding from the Energy Commission's PIER Program; 2) Precision Combustion's rich/lean catalytic system, which has been co-funded by the federal DOE; and 3) LBNL's low-swirl burner, whose development was funded by DOE and is being tested at Solar Turbines' expense.

The goal of this RD&D effort is to see one or more of these ultra-low NOx combustion technologies be placed into a long-term operation in a pre-commercial industrial gas turbine demonstration project, with subsequent

introduction into California's distributed generation power market. Testing of the first engine prototypes is expected to be completed by the end of 2007.

10. ASSESSING CLIMATE RISKS AND STATE POLICY RESPONSES

Through the PIER Program Environmental Area, the Energy Commission supports research of the environmental impacts of California's energy production, delivery, and consumption. The goal is to benefit California's ratepayers by enhancing the state's overall environmental quality while providing the energy services necessary for a healthy economy.

Because of the inextricable link between energy production from fossil fuels and greenhouse gas emissions, research into global climate change—and in particular, its effects on California—is a vital portion of the overall mission of the Energy Commission. However, such research involves the integrated efforts of a multitude of experts, focusing their research on the complex microclimates, topographies, ecosystems, land uses, and economic structures that comprise the state. Therefore, the Energy Commission had to determine how best to address this challenge with a limited budget and resources.

California Climate Change Center

The Energy Commission's global climate change research dates back to 1998, when it collaborated with the University of California to provide a report to the Governor and the California Legislature that examined the science surrounding the global climate change debate. In 2003, the Energy Commission built upon this early environmental research by collaborating with a variety of entities to examine potential climate change impacts on California. The resulting report concluded that such impacts would be costly to the state and that its diversity of ecosystems would be particularly vulnerable.

This legacy of successful collaborative research among entities statewide led the Energy Commission to create the California Climate Change Center in 2003. This "virtual" research center is composed of core research efforts at Scripps Institution of Oceanography and the University of California at Berkeley, as well as substantive complementary research activities at other research institutions. The groundbreaking research conducted by the Center assesses the risks posed to California by global climate change and evaluates mitigation options and adaptation strategies within an economic framework. The Center's research is developing the scientific knowledge necessary to weigh the costs and benefits of broader climate change response strategies. This research, in turn, can then be used by state and local agencies and the private sector to shape climate change coping strategies.

With funding of roughly $6 million annually, the Center is conducting research to address these overall questions:

- What are plausible climate scenarios for California?
- How would the physical impacts of climate change affect California's environment?

- What are the relative pros and cons of different climate change mitigation and adaptation strategies?
- How is climate change affecting energy supply and demand?
- What are the economic impacts of climate change on California?

Because SB 1250 explicitly directs the Energy Commission to address greenhouse gas emission reductions, the creation of the California Climate Change Center is an excellent venue to pursue this state energy policy goal within the context of state energy RD&D. A prime beneficiary of this research is the CARB, since it must evaluate options to reduce greenhouse gas emissions under AB 32, the Global Warming Solutions Act of 2006.

The use of this "virtual center" structure is emerging as a model for future RD&D because it links experts in various disciplines and locations via telecommunication networks. This collaborative approach efficiently maximizes existing assets and enables new partnerships to flourish.

"With such a complex topic as climate change, relying upon a virtual center is a very interesting approach," said Chet Koblinksy, director, Climate Change Office, National Oceanic & Atmospheric Administration. "There is a need for diverse expertise. No one place can do all of the necessary research. Given these circumstances, these virtual centers become a necessity," he added.

California Climate Change Center Partners
(a partial listing)

California Air Resources Board
California Department of Food and Agriculture
California Department of Forestry and Fire Protection
California Department of Water Resources
California Environmental Protection Agency
California Integrated Waste Management Board
California Resources Agency
Kearney Foundation of Soil Science
National Oceanic and Atmospheric Administration
U.S. Department of Energy

Research Success Stories
The following sections provide three examples of cutting edge research undertaken by the California Climate Change Center.

Climate Monitoring, Analysis, and Modeling
The Center has installed meteorological and hydrological sensors in key remote areas to better understand and document how California's climate is changing. Sensors have been installed in Yosemite National Park, the Santa Margarita Ecological Reserve, and the White Mountains. Research using this sensing infrastructure's data is contributing to understanding of important processes, such as how elevation affects snow melt conditions. Such information is crucial to project climate change effects on water and other state resources.

10-meter tower with sensors

Electronics enclosure mounted on tower

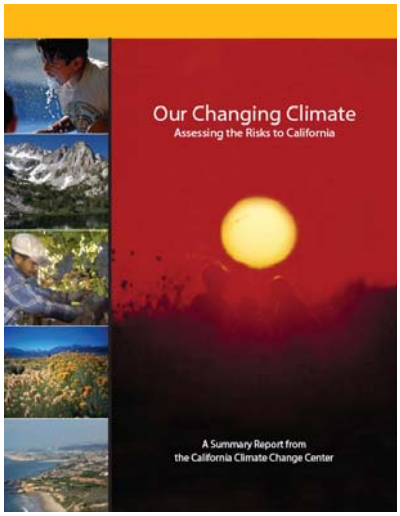
To assist policy makers, the Center is developing in-depth climate change scenarios for California. These scenarios will use the geographic and temporal resolution necessary for both research and long-term planning. Preliminary studies in this area have shown, for example, that irrigation in agricultural areas may have resulted in regional cooling—offsetting, in part, California's warming climate.

Energy Commission Research Is Recognized Globally

Researchers associated with the Center have published their findings in well-respected scientific journals. For example, scientists from Scripps have shown that precipitation in the Sierra Nevada is increasingly falling in the form of rain, rather than snow. This shift could affect water storage strategies in California significantly. The World Resources Institute declared this work one of the major breakthroughs in climate change science in 2005. More recently, the same Scripps group published a paper in *Science* reporting an increase of large forest fires in the western United States. The researchers demonstrated a statistical association between large fire events and the early onset of snow melts caused by higher ambient temperatures. This work has been widely acclaimed and received extensive press coverage.

Climate Scenarios Project

An Executive Order signed by the Governor on June 1, 2005, requires the California Environmental Protection Agency (CalEPA) to prepare biennial reports on the potential impacts of climate change on California. Given the strong scientific program on climate change already in place at the Energy Commission, the Center was asked to lead and coordinate the preparation of the 2006 report to the Governor and Legislature.



For this report, the Center developed 20 highly technical papers analyzing issues such as potential impacts of climate change on agriculture and energy and water resources. The multidisciplinary nature of this scenario analysis research served as the basis for evaluations of California climate change impacts at the state government's top levels. The report was released in early 2006, and its findings were included in the Climate Action Team Report of March 2006.

> "The quality of research contained in the scenario analysis performed by PIER far exceeded our expectations. The findings of the report contributed greatly to our understanding of the effects of climate change emissions in California. These findings were the basis of the scientific evidence reflected in the March 2006 Climate Action Team report and in AB 32, the California Global Warming Solutions Act of 2006.
>
> Eileen Wenger Tutt
> California Environmental Protection Agency
> Assistant Secretary for Climate Change Activities

The non-technical summary version, titled "Our Changing Climate," engendered multiple media reports, which contributed to an increased public understanding of climate change activities in the state. The Energy Commission and its Center are leading the preparation of the 2008 scientific report, in coordination with other state agencies.

West Coast Regional Carbon Sequestration Partnership

One of seven partnerships established by the U.S. Department of Energy in 2003, the West Coast Regional Carbon Sequestration Partnership (WESTCARB) is an RD&D effort managed and co-funded by the Energy Commission and designed to evaluate the feasibility of capturing carbon dioxide (CO_2) and storing it in appropriate geological reservoirs and terrestrial ecosystems such as forests. This approach—commonly referred to as "carbon sequestration"—can capture greenhouse gases that would otherwise contribute to climate change.

Beyond California, WESTCARB's members include the Alaska, Arizona, Nevada, Oregon, and Washington, and British Columbia. To date, WESTCARB researchers have discovered that California offers outstanding geologic sequestration opportunities and the potential for value-added benefits from enhanced oil and natural gas recovery. Research shows that saline formations in the 10 largest sedimentary basins in California could potentially store up to 5,000 years' worth of the state's current power plant and industrial-sector emissions.

Researchers carried out a preliminary source-sink matching and costing analysis for CO_2 storage in California that included capture, transportation, and injection costs. The results of this preliminary analysis indicate that 20, 40, or 80 million metric tons of CO_2 per year could be sequestered in California at a cost of $31, $35, or $50 per metric ton, respectively. To put these figures in perspective, California would require approximately 40 million metric tons of CO_2 of sequestration to offset greenhouse gas emissions from the state's fossil fuel power plants.

Researchers developed a framework for screening and ranking candidate sites for geologic carbon sequestration based on health, safety, and environmental risks. In addition, the research team created a Web-based, state-by-state compilation of current regulations, permits and contracts for injection wells (which govern geologic sequestration sites).

California Becomes National Model

According to the U.S. Climate Change Science Program, “California is unique in the United States as a state that has examined possible effects of climate change on its energy production and use in some detail.” In a November 2006 draft report titled *Effects of Climate Change on Energy Production and Use in the United States*, this report goes on to note that the Energy Commission—working with EPRI, the University of California at Berkeley, and Scripps Institution of Oceanography— “is developing a knowledge base on this subject that could be a model for other states and regions (as well as the nation as a whole).”