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FINAL PROJECT REPORT

PIER DEMONSTRATION PROGRAM: STATE PARTNERSHIP FOR ENERGY EFFICIENT DEMONSTRATIONS 2004-2010

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This report is dedicated to Mr. Donald Aumann, who passed away suddenly during the course of the program. Don was passionate about energy efficiency and the importance of advanced technologies to reduce energy consumption and greenhouse gas emissions. He was a tireless worker and inspiration to all who work on this program. His knowledge, enthusiasm, and optimistic view of the future are greatly missed.

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PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Energy Research and Development Division conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The Energy Research and Development Division strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

Energy Research and Development Division funding efforts are focused on the following RD&D program areas:

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- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

PIER Demonstration Program is the final report for the State Partnership for Energy Efficient Demonstrations (originally UC/CSU Energy Efficient Campuses) project (Contract Number 500-02-004, Work Authorization Number MR-022) including Amendment #1, conducted by the California Institute for Energy and Environment. The information from this project contributes to Energy Research and Development Division's Buildings End-Use Efficiency and Industrial/Agricultural/Water End-Use Energy Efficiency Programs.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

The State Partnership for Energy Efficient Demonstrations program promoted the market adoption of energy-efficient technologies developed by the California Energy Commission Public Interest Energy Research Program from March 2004 through June 2010. This public-private collaboration included field research, beta testing, demonstrations, and activities advancing the deployment of various California energy efficiency programs that were developed or advanced through this program.

This report is a compilation of the technologies and projects, technical reports, case studies, guide specifications, and other documents created through this program. More than 100 demonstration, field test, and technology transfer projects were conducted, including dozens of technologies from the Public Interest Energy Research Buildings End-Use Efficiency and Industrial/Agriculture/Water End-Use Efficiency Areas. The program initially focused on University of California and California State University campuses and was aligned with the University of California/California State University/Investor-Owned Utility Energy Efficiency Partnership—a public purpose-funded implementation program administered by the California Public Utility Commission to increase energy efficiency on California campuses. The program later expanded to include California Community College campuses, state agency and local government facilities, and private organizations.

This program accelerated market adoption of several technologies, including bilevel stairwell and exterior/parking lighting, integrated classroom lighting, integrated office lighting, and wireless lighting and heating ventilation and air conditioning controls. Several technology transfer tools facilitated this migration to market, including case studies, guide specifications, technology catalogs, training program curricula, virtual tours, and geographical information systems demonstration mapping. State Partnership for Energy Efficient Demonstrations Program efforts resulted in Public Interest Energy Research technologies being included in California Public Utility Commission/investor-owned utility-administered third-party implementation programs and American Recovery and Reinvestment Act State Energy Program economic stimulus programs. These program-demonstrated technologies could eventually reduce annual California energy use by at least two billion kilowatt-hours and eight million therms.

Keywords: California Energy Commission, Public Interest Energy Research, State Partnership for Energy Efficient Demonstrations, emerging technologies, energy-efficient, market transformation, lighting, heating, ventilation, and air conditioning, demonstration, valley of death, energy savings, building efficiency

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EXECUTIVE SUMMARY

Introduction

The California Energy Commission created the State Partnership in Energy Efficiency Demonstrations Program in 2004 to transform the market for technologies developed or enhanced with Public Interest Energy Research Program (PIER) funding. The program partnered with industry, public entities, and utilities to overcome the market barriers facing these innovative energy-efficient technologies so they could succeed in the marketplace and help California achieve significant energy, peak-demand, and carbon dioxide (CO_2) savings.

New technologies face a multitude of market introduction barriers that need to be overcome before they become stable and successful. These barriers are known as the "valley of death" because the technologies can never achieve broad success unless they surmount them. Emerging PIER technologies also face these barriers, which include lack of customer knowledge and marketing and distribution channels, higher markups from designers and installers, mistrust of savings and benefits organizations, and many more.

Project Purpose

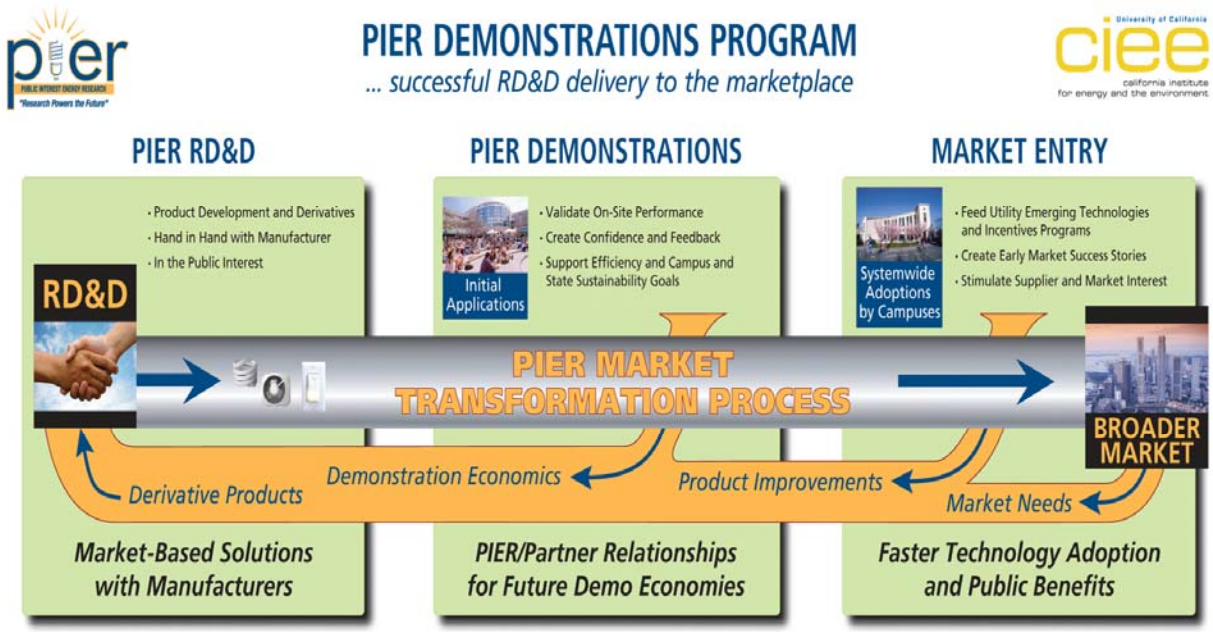
The State Partnership in Energy Efficiency Demonstrations Program was designed to help companies that implement PIER technologies cross the "valley of death" and gain a foothold in the marketplace. The Energy Commission's PIER Buildings Efficiency and Industrial Agriculture and Water End-Use Energy Efficiency Areas provided $6.75 million from mid-2004 through mid-2010 to demonstrate and field-test promising PIER technologies, transfer technologies, and otherwise support and encourage their success.

As the performing institution for this program, the University of California (UC) California Institute for Energy and Environment led the planning, implementation, and documentation of the demonstration projects and other activities, with help from several primary team members. These organizations included the Architectural Energy Corporation, the California Lighting Technology Center at UC Davis, the Pacific Gas and Electric Company's Food Service Technology Center, Lawrence Berkeley National Laboratory, and the Western Cooling Efficiency Center at UC Davis. Architectural Energy Corporation, the Food Service Technology Center, and the Western Cooling Efficiency Center were responsible for non-lighting technologies, and the California Lighting Technology Center was responsible for lighting technologies and coordination of technology transfer activities. Other special projects conducted by Lawrence Berkeley National Laboratory (LBNL) were for design guides, monitoring-based commissioning, benchmarking, and energy information systems. Monitoring-based commissioning (MBCx) is an approach combining permanent building-energy-system monitoring with standard retrocommissioning practices to provide substantial, persistent energy savings. LBNL also coordinated demonstration and field-testing of novel data center-cooling technologies.

Figure ES-1 illustrates the market transformation process. PIER works with manufacturers in the research, development, and demonstration phase to evaluate and develop products that meet identified energy and market needs. The program then partners with public and private

stakeholders to conduct prototype demonstrations in public facilities to validate the field performance of each commercial PIER technology. Partnerships among these varied stakeholders greatly increase the efficiency of the demonstration program and provide expert feedback for product improvements. This collaboration leads to adoption by energy efficiency implementation programs and purchases of the technologies, which supports state energy and sustainability goals. The program also links to electric utility programs and incentives, advises code changes in Title 20 and Title 24, stimulates market demand and supplier interest, and identifies customer needs for derivative products. As a whole, this market transformation pipeline leads to faster and more widespread market adoption.

Figure ES-1: The Innovative State Partnership for Energy Efficient Demonstrations (SPEED) Market Transformation Process



The first three years of the program (2004–2007) focused on developing partnerships with nine of the 10 University of California and eight of the 23 California State University campuses, which offered to demonstrate more than a dozen new PIER technologies. A second focus was to build the capabilities of the California Lighting Technology Center and partner with the University of California/California State University/Investor-Owned Utility Energy Efficiency Partnership to help campuses meet their energy efficiency goals. In 2007–2010 the program expanded beyond the 33 campuses to encompass California community college campuses, state agencies, Silicon Valley Leadership Group organizations, energy service companies, and others, as well as adding many new technologies to the demonstration portfolio. In 2007-2010 there were three main objectives: (1) continue supporting the first set of PIER technologies in the new market sectors; (2) introducing the newer technologies into all of the target markets; and (3) shifting to a variable cost-share demonstration model to leverage PIER funding more effectively and to enable substantially more demonstrations.

Project Results

The program accomplished its objectives through a variety of technology transfer activities, including demonstrations, case studies, fact sheets, websites, market education and training, group purchasing, public specifications, Title 24 code changes, utility incentives, and other methods. All of these efforts helped emerging PIER technologies gain market success, achieve maximum energy and cost savings, and expand the effect of PIER research, development, and demonstration investment. Over 100 individual demonstrations, field tests, and special technology transfer projects were conducted through this program focusing on several areas:

- Indoor and outdoor lighting.
- Heating, ventilation and air conditioning (HVAC).
- Energy management.
- Industrial, agricultural and water.

The program conducted market transformation activities for 34 emerging PIER technologies since its inception in 2004. One example of an emerging technology that illustrates the elements of the entire process was the LaMar bilevel stairwell fixture and the derivative "smart" exterior lighting fixtures. The State Partnership for Energy Efficient Demonstrations Program in California and the New York State Energy Research and Development Authority in New York initially jointly demonstrated the bilevel stairwell fixture in 2005–2006, including energy monitoring. Most of the 17 program-participant campuses in California requested demonstration of the bilevel stairwell fixture.

A group purchase was organized for the entire system once 10 campus demonstrations were completed. State universities require competitive bids for products, but the bilevel stairwell fixture had only one manufacturer. Program staff worked with staff at the UC Santa Barbara campus on a sole-source justification to overcome this barrier. The next step was collaborating with the University of California Strategic Purchasing committee for their first group purchase of a sole–source, energy-efficient product. The sole-sourcing aspect of the process was often necessary early on but only until multiple manufacturers start producing acceptable alternate products. Program staff worked with the Green Campus Interns program (funded by the University of California/California State University/Investor-Owned Utility Partnership) as part of the group purchase process. Program staff trained them to work with the campus energy managers to conduct campus audits of the stairwell lighting and make recommendations for the bilevel stairwell systems.

Also early in the process, the bilevel stairwell fixture won a best technology award at the 2005 LightFair International trade show, and the utility emerging technology programs demonstrated the bilevel stairwell fixture and included it in their rebates and incentives in 2006–2007. A number of campuses, including UC Los Angeles implemented campuswide programs to install bilevel stairwell fixtures and make them the standard campus specification.

Three additional lighting-fixture manufactures now make and promote a bi-level stairwell fixture. These companies were manufacturing partners of the California Lighting Technology

Center and were working with the center on these products. The bilevel stairwell concept was expected to be included into the 2011 revisions to Title 24.

The program also used the knowledge gained from research, development, and demonstration to improve emerging products throughout the development cycle and to develop ideas for associated energy-efficient products in new applications. The research, development, and demonstration conducted for the bilevel stairwell fixtures led to development of a portfolio of bilevel exterior parking and pathway fixtures using light-emitting diode, induction, fluorescent, and metal halide light sources. As a result, 16 "smart" (bilevel) exterior retrofit demonstrations were completed.

An initiative for retrofitting the parking and pathway lighting for all 10 University of California campuses was organized, working with the University of California Strategic Purchasing Committee. The UC campuses at Davis and Irvine were retrofitting their exterior lighting, and a similar program was being developed with California's Department of General Services for other state facilities.

A second set of bilevel derivative products was being developed for "smart" interior lighting for corridors and other areas. The California Lighting Technology Center was working with manufacturing partners to develop and field-test prototypes.

The program also achieved success with these technologies in other areas. The bilevel stairwell and exterior fixtures were being used in several of the California Energy Commission's American Recovery and Reinvestment Act State Energy Program projects. Bilevel parking requirements were being proposed for the next revisions of both ASHRAE 90.1 and the Energy Commission's Title 24. In addition, the Clinton Foundation worked with PIER and the City of Anchorage, Alaska to demonstrate light-emitting diode street and parking fixtures and promoted these successful demonstrations to the annual United States Conference of Mayors and internationally.

The bilevel stairwell fixture example illustrates the success of the highly leveraged, collaborative strategy for getting technologies through the "valley of death" and effectively into the marketplace.

One measure of the program's overall effect is the California statewide energy savings resulting from achieving the market potential of the demonstrated technologies in retrofit applications. Table ES-1 provides high and low estimates for energy savings from a partial set of 25 program technologies.

Table ES-1. Market Potential of State Partnership for Energy Efficient Demonstration Program Technologies

	Annual Electricity Savings (kilowatt-hours, kWh)	Annual Natural Gas Savings (therms)	Reduction in Annual Carbon Emissions (Tons of carbon dioxide equivalent, CO_2e)	Annual Monetary Savings	Lifecycle Monetary Savings
Low Retrofit Market Penetration	2,146,000,000	8,117,000	788,000	$287,000,000	$4,306,000,000
High Retrofit Market Penetration	5,365,000,000	20,284,000	1,969,000	$718,000,000	$10,766,000,000

Notes: Assumed Low Retrofit Market Penetration is 10 percent of all commercial and institutional floor space

Assumed High Retrofit Market Penetration is 25 percent of all commercial and institutional floor space

0.69 pounds of carbon dioxide equivalent (CO_2e) per kilowatt hour (kWh)

11.65pounds of CO_2e per therm

$0.13 per kWh

$1.00 per therm

15-year equipment life

Progress toward achieving this market potential in the achieved or targeted savings of major implementation programs resulting from program technology transfer included:

- Municipal and Commercial Building Targeted Measure Retrofit Program (State Energy Program/American Recovery and Reinvestment Act).
  Downtown Oakland Targeted Measure Saturation Program.
  Target: 8.4 million kilowatt hours (kWh) and 138,500 therms per year.
- Municipal and Commercial Building Targeted Measure Retrofit Program (State Energy Program/American Recovery and Reinvestment Act).
  Energy Technology Assistance Program.
  Target: 20.7 million kWh and 243,200 therms per year.
- State Energy Program/American Recovery and Reinvestment Act.
  Active Management of Cooling Systems to Reduce Energy Consumption for the Data Center Market (Datacenter Automation Software and Hardware).
  Target: 4.7 million kWh per year.
- Pacific Gas and Electric High Performance Office Lighting Systems Third-Party Program.
  Target: 40.5 million kWh per year.

- Pacific Gas and Electric Kitchen Demand Controlled Ventilation Third-Party Program.
  Target: 28.6 million kWh and 1.7 million therms per year.
- EnerNOC/Pacific Gas and Electric Company Monitoring-Based Commissioning Third-Party Program.
  Target: 21.5 million kWh and 180,000 therms per year.
- EnerNOC/Southern California Edison Monitoring-Based Commissioning Third-Party Program.
  Target: 24 million kWh per year.
- University of California/California State University/Investor-Owned Utility Energy Efficiency Partnership Monitoring-Based Commissioning Program.
  Savings accumulated from 2004 through 2009: 31 million kWh and 2.8 million therms per year.
- Additional Monitoring-Based Commissioning project potential identified in University of California Strategic Energy Plan Project Portfolios
  Target: 33 million kWh and 3 million therms per year.

The new, interactive market transformation process developed by this program strongly supported the PIER Program energy efficiency areas and created a variety of tangible benefits to California. The major accomplishments included:

1. **The technologies developed with research, development, and demonstration funding have entered the market**. The program created a market pull by deploying technologies into the University of California and California State University campuses so that they were available for other sectors of the commercial buildings market. These and other organizations were specifying PIER technologies in their retrofit and new construction projects. For example, Chevron Energy Solutions, a major energy service company, recommended that the bilevel stairwell fixtures be used for a post office retrofit. Disney Resorts in Hawaii was installing the bilevel stairwell fixture and was considering other research, development, and demonstration technologies.
2. **Results of the performance evaluations have gone back to the PIER Program.** Those results suggested further productive research, development, and demonstration, such as derivative products and product improvements. Not all of the technologies were ready for wide commercialization, but ideas for derivatives of products were developed during testing and analysis and reported back to the PIER Program. Examples include the bilevel exterior lighting systems, the Integrated Office Lighting System, and the Discharge Air Regulation Technique, and Data Center Automation Software and Hardware systems. Two lighting derivative products won several industry awards from the U.S. Department of Energy and the lighting industry, and the Discharge Air Regulation Technique won a California Clean Technology Open award.
3. **Results have gone to utilities so they can be included in emerging technology programs and incentive programs.** Program demonstrations have developed performance data for utilities to use as they develop their incentive programs. Emerging technology program managers have visited the California Lighting Technology Center to see what technologies

are ready for the emerging technology pipeline. Emerging technology programs have also partnered with the program in demonstrations and conducted additional field-testing of almost all of the PIER technologies in the program portfolio. This collaborative relationship leveraged the market adoption of PIER technologies and helped the emerging technology groups serve the special needs of the utility deployment and incentive programs.

4. **Results have influenced California Energy Commission-developed codes and standards.** Program demonstrations have shown that codes can have more aggressive energy efficiency goals because products were available to meet them. Results of the demonstrations have been communicated to the codes and standards group at the Energy Commission for use in developing the next versions of Title 24. Examples included the residential bathroom occupancy sensor and lower power densities for classrooms and offices.
5. **Program results have prompted manufacturers to enter the market**. Products similar to or even better than the PIER technologies have been developed and introduced to the market. This leveraged or magnified the influence of the PIER Program and the benefits were more available to state organizations and to the public. For example, about 20 different manufactures were making products similar to the Integrated Classroom Lighting System, the bilevel stairwell fixtures, "smart" exterior lighting fixtures, and demand-controlled kitchen ventilation systems. Demand control ventilation optimizes energy efficiency by reducing the exhaust and make-up air fan speed. One key example of the market influence of the program was the development of the "smart" occupancy-based control of parking and exterior fixtures and the introduction of light-emitting diode and induction technologies. More than a dozen manufacturing partners produced a large array of "smart" exterior fixtures and were shifting the market to these new technologies.
6. **Success stories have been created.** More than 50 case studies or fact sheets were developed to showcase the successful products, much earlier than for a typical commercialization process. These have contributed to faster technology adoption by California university campuses, as well as exposing the broader commercial building market to the verified performance of PIER innovations.
7. **The broader market is now aware of options that were previously not available.** Raising market awareness was another step in promoting the PIER technologies. Documented demonstration results and case studies on a significant number of buildings helped to build confidence in the new technologies and reduced early adopter risks. The program produced a large and varied number of technology transfer and market communication materials and activities including case studies, technical briefs, several design guidebooks, new construction specifications, dozens of major presentations per year, websites (including a Google map-based site), training and education, and published papers.
8. **Successful new companies have created jobs and investment opportunities.** Several new companies have evolved out of PIER research, development, and demonstration projects, and many more have added products and jobs. In addition, several new companies, such as Adura Technologies and Federspiel Controls, have won awards in the California Clean Technology Open.

9. **Out-of-state impacts.** The market transformation effects expand beyond California. A few examples include:
    a. **New York State Energy Research and Development Authority.** Because of its participation in the demonstration program, the authority was interested in using the PIER market transformation model in New York.
    b. **City of Anchorage, Alaska, and the Clinton Foundation.** Demonstration results led the city of Anchorage, Alaska to retrofit street and parking lighting with light-emitting diode fixtures. The Clinton Foundation has taken the light-emitting diode and bilevel exterior concepts globally.
    c. **U.S. Department of Energy Partnership.** The U.S. Department of Energy will use the Merced cooling efficiency field-test results nationwide to improve the operation of central chiller systems.
    d. **ASHRAE 90.1.** Program technology demonstrations have influenced the ASHRAE energy efficiency codes in a number of cases. Two examples were the recommendation for demand-controlled commercial kitchen ventilation systems and the bilevel parking garage lighting systems. The June 2010 proposed ASHRAE Standard 90.1 revisions included bilevel parking garage lighting systems, and the program is providing data to support the proposal.

Overall, the program proved to be a very effective way to leverage research development investments providing programmatic assistance to help the PIER technologies get over the "valley of death" and into the marketplace. Demonstration partnerships not only provided field verification, but provided the host organizations with new and better solutions to help reach their energy and sustainability goals. The initial partnerships with university campuses allowed a large public sector entity to take the lead in purchasing and implementing these new technologies and helped the companies associated with the PIER Program overcome many of the market introduction barriers.

Another measure of effectiveness was that a large number of demonstrations were enabled by the initial coordination with university campuses. One of the more time-consuming tasks in technology demonstration projects is identifying locations where the demonstrations can be conducted and developing agreements between the researchers and the property owners. The advantage of working with campuses was that contact with one person yielded multiple buildings in which to demonstrate technologies, as well as being able to demonstrate more than one technology per campus. Less time was devoted to finding test sites and coordinating agreements and fewer trips were needed to test sites. This program was therefore able to do more testing with less money than is typically possible.

The university research, development, and demonstration centers conducting many of the demonstrations proved particularly effective in working with both public and private sector researchers, as well as coordinating with host sites. The mix of faculty, students, and full-time professional research staff at these centers was key to this success.

There is a need to accelerate the market adoption of the products of PIER research and demonstration programs. The State Partnership for Energy Efficient Demonstrations Program effectively met this market-transformation need by employing case studies, guide specifications, technology catalogs, and a variety of other technology transfer tools to cross the "valley of death" that often stalls new technology. The nimble approach taken by the program was necessary to maximize the dispersion of technology and applications knowledge in diverse market settings. The program was very effective in promoting integration of new technologies into utility energy efficiency and economic stimulus programs.

An effective demonstration and information dissemination program can not only provide case study information to enable accelerated technology adoption, but can provide the feedback crucial to the creation of new "derivative" products, including new classes of products with expanded applications. The program was highly successful in stimulating manufacturers to offer more new technologies in their product lines.

A university research, development, and demonstration center was an effective model for demonstration activities, with the right mix of faculty, student, and staff to conduct and document demonstration projects. University research, development, and demonstration centers can work with both university and private technology providers in demonstrating and evaluating technology.

Higher education campuses can provide a good setting for technology demonstration. The culture of learning and professional accomplishment often found among facility personnel leads to a desire to try new things and the opportunity to demonstrate newer technologies. Students and faculty add to the rich innovation environment, along with leadership present in systemwide management that minimizes the effort needed to organize demonstration activities.

The program was highly successful in fostering new manufacturers to offer products and develop new product lines based on demonstrated technologies. The program also strongly supported the evolution of codes and standards tracking new technology, as well as compelling institutional organizations to adopt demonstrated technologies as internal standards. The program enabled integration of demonstrated technologies into utility energy efficiency and economic stimulus programs, as well as addressing the goals of the California Long-Term Energy Efficiency Strategic Plan. Program activities were recognized with multiple awards, which resulted in accelerated market adoption of new energy efficiency technology.

The program will continue to promote market adoption of new technology through ongoing demonstrations, special technology transfer projects, and market transformation activities in follow-up phases. Acceleration of technology adoption can continue in more market sectors and for more PIER products with continued demonstration program efforts. Executive Order S-20-04 calls on all public education, government, and private sector entities to reduce energy use. The program can support this imperative though activity across all sectors, especially by expanding efforts with local government and private organizations.

The historical level of funding for the State Partnership for Energy Efficient Demonstrations Program will need to be maintained to sustain momentum toward the expansive and

comprehensive statewide goals. Increased funding could be effectively used to achieve even more rapid and widespread adoption of PIER technology and progress toward program goals. Leveraging of program funding with resources from deployment programs and demonstration host sites would maximize program effectiveness. The program process might be replicated for other California Energy Commission programs or in other states.

Project Benefits

This program exemplifies PIER's goals of developing strategic public-private partnerships to build on successful research, development, and demonstration leverage investments throughout the state, and to deliver practical, quantifiable energy and economic benefits to California and its residents. These technologies demonstrated in this program could eventually reduce annual California energy use by at least two billion kilowatt-hours and eight million therms.

CHAPTER 1: Introduction

The California Energy Commission's Public Interest Energy Research (PIER) Program supports energy research, development, and demonstration (RD&D) projects that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.[1] These RD&D projects have produced energy-efficient technologies and practices ready for demonstration and large-scale deployment. To facilitate the introduction of these new technologies to real-world applications, PIER formed a partnership with the University of California (UC) and California State University (CSU). This partnership later expanded to include community college districts, state agencies, Silicon Valley Leadership Group organizations, and other market sectors.

In 2004, the California Energy Commission contracted with the California Institute for Energy and the Environment (CIEE)[2] to carry out what was then called the Energy-Efficient UC/CSU Campuses Program. The California Institute for Energy and the Environment installed, monitored, evaluated, and reported on the performance of a group of technologies that had recently been developed with funding from the PIER program. The Program supported California's goal to maximize the energy-efficiency potential of existing buildings as prescribed by the *2003 Integrated Energy Policy Report* (Energy Commission 2003), California Executive Order S-20-04 (Executive Order S-20-04 2004), the *California Energy Action Plan* (Energy Commission and CPUC 2005, ENERGY COMMISSION and CPUC 2008), and the *California Green Building Action Plan* (State of California 2005).

The Program's main goals are to:

- Transfer PIER-sponsored technologies to a large, existing commercial sector.
- Gain working experience with these innovative technologies so that more informed decisions could be made regarding their use in relevant, large-scale applications.
- Gain new knowledge of the energy-efficiency of institutional and commercial facilities in the State of California.[3]

The Program is designed to catalyze the introduction of new technologies to the market and help bridge the "valley of death" created by the market's reluctance to purchase sufficient quantities of new technologies, thereby enabling them to become "mainstream."

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1 PIER. California Energy Commission. Home page. 21 November 2007. January 2, 2008. www.energy.ca.gov/pier/index.html.

2 CIEE is a systemwide unit of the University of California, part of the University of California Office of the President through mid-2009 and now hosted by the Berkeley campus.

3 PIER. California Energy Commission. State Partnership for Energy Efficient Demonstrations. January 2, 2008. www.energy.ca.gov/pier/portfolio/Content/06/Buildings/State%20Parternship%20for%20Energy.htm.

At about the same time the program began, the Energy Efficiency Partnership was formed between California's four investor-owned utilities (IOUs), UC, and CSU. The Partnership was designed to provide a sustainable energy-management framework for the 33 university campuses served by the IOUs.[4] In particular, the Partnership provided UC and CSU campuses with resources and funding opportunities for energy-efficiency projects. Campus facility and energy managers were now able to select appropriate energy-efficient technologies, including those PIER technologies demonstrated through the Program, and finance the improvements through the Partnership. In addition, educational services for campus personnel were developed with curricula including substantial PIER content. Thus, the Partnership provided an avenue to disseminate information generated during the Program and assist campuses financially with future energy-efficiency projects.

The Program was extended for another three years in 2007. The extended program was re-named the State Partnership for Energy Efficient Demonstrations (SPEED). It was expanded to include community college districts, state agencies, local governments, special districts, and Silicon Valley Leadership Group organizations.

1.1 Program Goals

One of the primary goals of the Program is to transfer PIER-funded building technologies and practices to major California market sectors—to help meet California's targets for energy efficiency and greenhouse gas emission reductions. Information collected during the program assists facility managers in making informed decisions regarding each technology's use in future retrofit, renovation, and new construction projects. To accomplish this goal, CIEE had the Architectural Energy Corporation (AEC) and the California Lighting Technology Center (CLTC) work with campuses and later with others to select and install appropriate PIER technologies, establish baseline facility energy efficiency and performance, and evaluate new technologies relative to the baseline energy performance. Lawrence Berkeley National Laboratory, the Western Cooling Efficiency Center, and other RD&D organizations were later added as team members.

Facility managers at host sites provide expert guidance and feedback on the field performance of the PIER technologies demonstrated. This feedback is used to improve and redesign the PIER products and to influence future research and development.

General Program objectives include the following:

- Measure and analyze PIER equipment performance against pre-retrofit baselines.
- Analyze technology integration with other building systems and components.
- Improve Title 24 and Title 20 energy-efficiency standards
- Identify institutional usage patterns.

4 UC/CSU/IOU Energy Efficiency Partnership. Home page. January 2, 2008. www.uccsuiouee.org/index.html.

- Document the retrofit process.
- Survey and document building operator response to new technologies.
- Identify potential product modifications and make recommendations based on users' responses to demonstrated PIER technologies.
- Build new partnerships with UC and CSU for future technology transfer activities.
- Develop case studies.
- Develop a new model for market transformation that accelerates the commercialization path for cutting-edge energy-efficiency technologies.

1.2 Report Organization

This final report covering the first six years of the program (March 2004 through June 2010) describes Program impacts and accomplishments, serves as an index and concise reference to Program activities, and provides an index to the hundreds of documents detailing Program elements. The major sections of this report and their intent are described below.

- Chapter 2, Technology Portfolio, describes the technologies that were included in the Program.
- Chapter 3, Program Partners, describes the organizations and programs that teamed with PIER to implement the program.
- Chapter 4, Demonstrations, describes the demonstration process and projects implemented by the Program to date, along with estimates of the potential energy savings from statewide adoption of demonstrated technologies and a listing of major deployment programs utilizing the technologies.
- Chapter 5, Education and Training, describes the Program support for the UC/CSU/IOU Partnership, Program participation in the California Higher Education Sustainability conference series, and the various Program products serving as outreach and technology transfer tools.
- Chapter 6, Market Transformation and Program Results, describes interactions with deployment programs, market transformation milestones, and other Program achievements.
- Chapter 7, Conclusions and Next Steps, summarizes the program's impact and describes plans for continuing its successful role in getting PIER Technology to market.

The report refers to hundreds of Program documents referenced as Attachments (see index of Attachments following the Table of Contents). These include technical reports, case studies, guide specifications, PIER technology catalogs, and other program documents. Among the attachments is a more than 300-page interim report describing the Program's first three years (2004–2007), including details of the early demonstrations.

CHAPTER 2: Technology Portfolio

At the beginning of the Program in 2004, CIEE, other Program team members and California Energy Commission PIER Buildings Energy Efficiency Area staff developed a candidate list of technologies for potential demonstrations. The candidate list emphasized commercial (and institutional) building technologies to fit the original target market of higher education campuses and the initial demonstration venue, consisting primarily of state-funded buildings on UC and CSU campuses (see Chapters 1, 3, and 4 for more information on this aspect of program planning). The PIER program was directly involved in the development of most of the technologies. However, a few very promising technologies, such as the bi-level stairwell fixture and kitchen demand controlled ventilation, were included with only peripheral previous involvement of PIER.

A screening process narrowed the candidate list of technologies down to a group of fifteen that were offered in an initial solicitation of host demonstration sites. Program team members conducted the screening process with attention to market readiness, as well as details of technology status, which sometimes only emerge as an actual demonstration is considered (for example, if enough product is available for the anticipated demonstration).

These technologies were developed primarily under PIER Lighting Research Program (LRP, Porter 2006) and contracts managed by AEC (Smith 2003), Lawrence Berkeley National Laboratory (Selkowitz 2003), the New Buildings Institute (Higgins 2003), and the Energy Innovations Small Grants (EISG) Program (Federspiel and Clark 2002). The technologies were divided into two groups: those that were market-ready and those still involved in beta testing. This was done so that the campuses would understand the risk in selecting certain technologies over others.

Between the time that the initial technologies were presented and the initial group of demonstrations was selected, the program selected two additional technologies to be offered to specific campuses. More details regarding the initial group of technologies can be found in the *PIER Energy Efficient Campuses Demonstration Program: 2004–2007 Interim Report* (see Attachment I—Interim Reports)

The Program also addressed technologies that do not fit into typical demonstration projects (for example, monitoring-based commissioning was beyond the demonstration stage, ready for scaled deployment). The program supported these technologies with special technology transfer projects or field testing.

Starting in 2007, the program added technologies to the list available for demonstrations both by systematic technology assessment (see 2008 Technology Assessment*: Initial Lighting Portfolio for Demonstration* in Attachment I—Interim Reports) and individually as they emerged from PIER research and development (R&D) programs. At this point, demonstration program feedback began to influence PIER R&D programs and technology development, resulting in product improvement or development of new classes of products. Such products are referred to

as *derivative products,* as they were partially derived from information gathered through the demonstration process.

Also in 2007, the Industrial/Agriculture/Water (IAW) End-Use Efficiency area began participating in the program. The program demonstrated selected IAW technologies as a result.

2.1 Lighting

The Program demonstrated a large sample of energy-efficient lighting controls and luminaires. Some lighting technologies were developed directly with PIER funding, while others were derivative products that came to market after initial PIER-sponsored development. *Derivative products* are equivalent products from new manufacturers, newer improved offerings of products improved at least partly as a result of information obtained during the demonstration process, or new classes of products for new applications developed at least partly as a result of the demonstration process. Derivative products illustrate the market impact of PIER-sponsored research and development on manufacturers. Manufacturers will often embrace the energy-efficient measures developed under the PIER umbrella and commercialize similar products based on these concepts. While some of these products were brought to market independent of PIER, they may be demonstrated as a part of Program market transformation efforts because of the technology lineage. The sections below summarize the categories of lighting products demonstrated; a more detailed summary of the lighting product demonstrations can be found in Chapter 4. Details of lighting technologies can be found in Attachment II—Case Studies and in Lighting Demonstration Site Reports (see Attachment III—Technical Reports).

2.1.1 Street and Parking Area Luminaires

An estimated 60 million street and area lights currently are in operation in the United States, and this number is expected to continue to grow over the next decades, as are concerns regarding energy efficiency and light pollution. To address these problems, the PIER program funded the development and demonstration of occupancy-based lighting controls and broad-spectrum light sources to create intelligent, bi-level luminaires designed for street and parking area applications. Program field monitoring and case studies show a 30 to 75 percent energy savings. For detailed information please see bi-level and area lighting (exterior lighting) case studies in Attachment II and the 2010 *PIER Solutions for Parking Lots and Garages* technology catalog (see Attachment IV—PIER Technology Catalogs). The bullets below identify each technology, the available case studies, and other information.

- BetaLED The Edge LED area light (case study, see Attachment II – Exterior Lighting, Bi-Level Street and Area Lighting)
- Everlast induction shoe box
- Everlast induction cobra head (case study, see Attachment II– Exterior Lighting, Bi-Level Street and Area Lighting)
- Everlast acorn walkway luminaire (non-Program installation in progress at the University of California Irvine [UCI])

- Hadco Lighting Evolair (demonstration in progress at the Los Angeles Trade Technical College [LATTC])
- Wide-Lite HIBRED™ (new derivative product, available for demonstration)
- Gardco Demand Response area lighting (new derivative product, available for demonstration)
- Wide-Lite Spectra II and Spectra III area lighting (new derivative product, available for demonstration)

2.1.2 Parking Garage Luminaires

Many parking garage structures in commercial and institutional facilities currently are continuously illuminated with high-pressure sodium and metal halide ceiling-mounted fixtures. Occupancy patterns are ignored, and entire garages often are lit during long vacant periods of vacancy or no traffic throughout the day and night. The PIER program funded the development and demonstration of garage fixtures that integrate light-emitting diode (LED) or induction sources and occupancy-based dimming controls. The bi-level controls provide energy savings directly proportional to automatic and pedestrian traffic patterns. Program field monitoring and case studies show a 30 to 60 percent energy savings. For detailed information please see case studies in Attachment II and the 2010 *PIER Solutions for Parking Lots and Garages* technology catalog (see Attachment IV—PIER Technology Catalogs). The bullets below identify each technology, the available case studies, and other information.

- BetaLED The Edge LED parking structure light (case study, see Attachment II)
- Everlast induction garage fixture (case study, see Attachment II)
- Day-Brite Vaporlume Series luminaire (case study, see Attachment II)
- Wide-Lite VizorLED parking garage luminaire (new derivative product, demonstration in-progress at City of San Marcos)
- Columbia BIL4 luminaire (new derivative product, available for demonstration)
- Lithonia Archway bi-level parking garage luminaire (new derivative product, available for demonstration)

2.1.3 Pathway Luminaires

Most bollard-style luminaires are used to light common areas, pathways, and sidewalks. They usually employ metal halide, high-pressure sodium, or compact fluorescent lamps. Such systems typically are operated all night at full output, regardless of occupancy. The PIER program funded the development of an innovative luminaire for pathway applications that directly addresses both system efficiency and occupancy patterns. The CLTC researchers developed a bollard that uses high-quality LEDs and microwave occupancy sensors to efficiently light the pathway and further reduce energy consumption during unoccupied periods. Program field monitoring and case studies show a 40 to 75 percent energy savings. For detailed information, please see exterior lighting case studies in Attachment II.

- Gardco BRM 800 series LED bollard (case study, see Attachment II – Bi-Level LED Bollards)

- BetaLED The Edge LED pathway light (new derivative product, available for demonstration)
- 3100 Series Bollard by Hydrel (new derivative product, available for demonstration)

2.1.4 Security Lighting

Exterior security lights often are used to bolster security and aid in way finding in evenings. While security lights effectively provide lighting around buildings, in the past they have suffered from many setbacks, including low fixture efficiency, minimal or nonexistent cutoff, and wasted energy because of low occupancy patterns. The CLTC has demonstrated wall packs that successfully address these issues; the luminaires project minimal light and have higher efficiency and lower operational costs. Program field monitoring and case studies show a 30 to 60 percent energy savings. For detailed information please see exterior lighting case studies in Attachment II and the technology catalog in Attachment IV—PIER Technology Catalogs).

- Day-Brite Nitebrites wall pack (for case study, see Attachment II – Bi-Level HID Wall Pack)
- BetaLED The Edge LED wall pack (new derivative product, available for demonstration)
- Gardco 121 LED sconce (new derivative product, available for demonstration)
- Everlast induction wall pack (new derivative product, available for demonstration)
- Gardco low-glare wall pack (product not available)
- Hunter Lighting hybrid smart entry luminaire (product not available)

2.1.5 Classroom Lighting System

Many classrooms provide mediocre lighting quality and have high energy costs. Although high-efficiency systems are available, they require a piecemeal approach when including automatic controls for occupancy and dimming. Classroom lighting systems can combine high-quality lighting, increased flexibility, daylighting, and energy efficiency into an affordable, easy-to-use, and easy-to-maintain single-source solution. With fewer fixtures, lamps, and ballasts, the operational and maintenance costs are reduced. Program field monitoring and case studies show a 30 to 60 percent energy savings. Detailed information is provided in interior lighting case studies (see Attachment II), derivative product descriptions (see Attachment V), and the 2009 *Solutions for Classrooms and Conference Rooms* technology catalog (see Attachment IV.

- Finelite Integrated Classroom Lighting System (ICLS) (case study, see Attachment II – Integrated Classroom Lighting System)
- Lithonia Classpack (derivative product, demonstration in progress at LATTC)
- Alera A+ Class system (derivative product, demonstration in progress at LATTC)
- Litecontrol CS/av (new derivative product, available for demonstration)
- Peerless CLS (new derivative product, available for demonstration)
- Cooper Smart Environments/InClass Command (new derivative product, available for demonstration)

2.1.6 Recessed Troffers

An ICLS derivative project was to develop recessed troffer versions to target the retrofit market and include the integrated occupancy and daylight sensing controls. Program field monitoring and case studies show a 30 to 60 percent energy savings. Detailed information can be found in the derivative product description (see Attachment V – Derivative Product Descriptions, Classroom Lighting Systems).

- Finelite High Performance Recessed (new derivative product, demonstration pending)
- Lamar LICOS series (new derivative product, available for demonstration)

2.1.7 Lamps/Ballasts

The key barriers to fluorescent dimming and controls are the first costs, the complexities of the commissioning and controls, and the lack of open-source control protocols. The Osram Sylvania PowerShed ballast evolved from PIER research and won a 2008 LightFair International technology award. The Hunter LED ceiling retrofit targets the residential model with the top manufacture of ceiling fans to allow dimming and reduce the lighting load by tenfold over the incandescent lamps. The Digital Addressable Lighting Interface (DALI) project, co-sponsored by the National Electrical Manufacturers Association (NEMA), is developing an open-source lighting controls protocol, NEMA 24. The PIER Program and CLTC are developing a set of lighting devices to go with the NEMA 243 protocol. These are still in development, with the protocol approval anticipated in early 2011. The device prototypes will follow later in 2011.

- Osram Sylvania PowerShed Demand Response ballast (beta test case study at UC Santa Barbara [UCB], see Attachment II)
- Hunter Fans LED ceiling fan retrofit kit (demonstration pending)
- Digital Addressable Lighting Interface (DALI) protocol (The DALI prototype demonstration was limited because of the lack of available technology and because the products are not yet commercially available, see Attachment III—Technical Brief, Open Digital Lighting Protocol.)

2.1.8 Recessed Downlights

Many builders and designers who could specify recessed downlight fixtures instead opt for larger fluorescent recessed troffers with either parabolic reflectors or prismatic lenses, which can produce a high level of glare. The CLTC developed two recessed downlights—one for compact fluorescent lamps (CFLs) and one for LEDs—that reduce both energy and installation costs while improving lighting quality. Program field monitoring and case studies show a 30 to 60 percent energy savings. Detailed information can be found in the interior lighting case studies (see Attachment II).

- Cooper HALO LED downlight (case study, see Attachment II)
- Lithonia CFL downlights (case study, see Attachment II, but product is not yet available on the market)

2.1.9 Lighting Controls

The CLTC has demonstrated, tested, and designed various lighting controls, each of which is designed to save energy and money while reducing the amount of time lights are on at full power. Program field monitoring and case studies show a 30 to 60 percent energy savings. Detailed information can be found in technical reports in (see Attachment III) and case studies (see Attachment II).

- Watt Stopper/Legrand LS-102 daylight controller
- Watt Stopper/Legrand WN-100 wall switch (case study, see Attachment II – Hybrid Vanity and Wall Switch)
- Adura WIPAM (case study with garage lighting at USCB, see Attachment II –Parking Garage Luminaires)
- Watt Stopper/Legrand DW-200 (and others)
- Dual-loop photosensor control system for daylight harvesting (commercial product not yet available)

2.1.10 Bilevel Surface-Mount Luminaires

Stairwell lighting typically operates continuously at full output despite very low, intermittent use. Simple occupancy sensors that turn fixtures on and off are not used because of building code requirements that prohibit zero light levels, even when unoccupied. The CLTC has demonstrated luminaires that dim to as low as 5 percent of normal with adjustable time delays that maximize energy savings based on usage patterns. Program field monitoring and case studies show a 40 to 80 percent energy savings. Detailed information can be found in interior lighting case studies (see Attachment II).

This promising technology was one of the exceptions included in the original demonstration portfolio with only peripheral previous PIER involvement. The PIER Program was later actively involved in the development of derivative bi-level ("smart") exterior lighting products and bi-level corridor lighting.

- Lamar Occusmart VO series luminaire (case study, see Attachment II – Bi-Level Stairwell Fixtures)
- Day-Brite Stairwell fixture (demonstration in-progress in progress at UCD and LATTC)
- Cooper Surelites (new derivative product, available for demonstration)
- Columbia BIL4 luminaire (new derivative product, available for demonstration)
- Ecovations stairwell luminaire (new derivative product, available for demonstration)

2.1.11 Task-Ambient Lighting

Office spaces traditionally rely on a lighting design approach referred to as general lighting, where ceiling-mounted luminaires provide an overall uniform level of illumination sufficient for both task and ambient lighting. Until recently, task/ambient systems were rare. Now, these lighting systems have shown the potential to yield a 40 to 50 percent energy savings and provide superior lighting and increased user satisfaction. Ambient lighting provides a uniform,

diffuse, low level of light for the general office space, while energy-efficient, high-quality personal task lighting is added to specific work areas. Detailed information can be found in case studies (see Attachment II).

- Finelite IOLS (case study, see Attachment II)
- Berkeley Lamp II (included in some demonstrations with IOLS)

2.1.12 Bathroom Smart Fixture (and Smart Switch)

This technology uses LED and fluorescent fixtures with integrated controls. The fluorescent lighting component provides full task lighting, while the LED component provides a low light level, energy-saving night-light function. When the bathroom is not in use, the LED function switches on; when an occupant is detected, the fluorescent lighting provides full light. (This fixture is not available at this time.)

- Acuity MetalOptics MBV Series Luminaire (case study, see Attachment II – Hybrid Vanity and Wall Switch, however this product is not available at this time)
- Watt Stopper WN-100 bathroom switch and HN-200/300 retrofit kit wall switch (case study, see Attachment II – Hybrid Vanity and Wall Switch)

2.1.13 Open Digital Communication Protocol for Lighting Systems

A key technical challenge for next-generation lighting systems is to provide individual building occupants with personal control of multi-luminaire, centralized lighting systems. The existing digital ballast protocol addresses this challenge in many ways by allowing zonal control of individual luminaires on a single circuit, with zone membership as small as single ballast. However, the current standard does have its limitations. To address some of these limitations, NEMA, in partnership with the California Energy Commission, developed an open digital communication protocol for complete lighting systems: *NEMA Standards Publication 243*, which is in the final stages of approval.

2.1.14 Daylight Sensor Placement and Optimization Tool (SPOT)

The Architectural Energy Corporation developed the Sensor Placement and Optimization Tool (SPOT) during the PIER RD&D Lighting Research Program to help with the placement of the daylighting photosensor in daylighting design. This tool helps create successful daylighting and electric lighting integration with maximum energy savings. It also quantifies existing or intended electric lighting and annual daylighting characteristics of a space and helps establish photosensor placement for proposed lighting designs.

2.2 Heating, Ventilation, and Air-Conditioning (HVAC)

The Program also showcased PIER Building Heating, Ventilation, and Air-Conditioning (HVAC) technologies, including:

- Air flow Measurement and Control (IAQ-42).
- Variable Air Volume (VAV) Static Pressure Reset and Discharge Air Regulation Technique (DART) for Constant Volume (CV) to VAV Conversions.
- Large Duct System Sealing.

- Demand Controlled Kitchen Ventilation.
- Advanced Variable Air Volume (HVAC) Design Guide.
- HVAC Fault Detection and Diagnostic Tools.
- Hybrid Rooftop Packaged Air Conditioners.
- Occupancy-Based Control.
- Chiller Optimization.

In addition, the Program promoted Lawrence Berkeley National Laboratory (LBNL)-developed Cool Roof technology for potential demonstrations (Akbari and Miller 2006). However, no viable host sites came forward; therefore, no demonstrations were conducted.

The sections below summarize the categories of HVAC products demonstrated; see Chapter 4 for a brief description of demonstration projects for these PIER HVAC technologies. More details of HVAC Technologies and Demonstrations can be found in Attachment II—Case Studies.

2.2.1 Air Flow Measurement and Control (Indoor Air Quality-42)

Federspiel Controls developed the Indoor Air Quality-42 (IAQ-42) Air Measuring Control Damper (Federspiel and Clark 2001). The IAQ-42 Air Measuring Control Damper is not something that would be installed to cost-effectively save energy, but it is worth considering for other reasons. For instance, it can be used to comply with the Leadership in Energy and Environmental Design-Existing Buildings (LEED-EB) credit for Outdoor Air Delivery Monitoring. It might also be used to comply with the LEED-EB credit for Increased Ventilation. The demonstration of this technology is documented in *PIER Energy Efficient Campuses Demonstration Program: 2004-2007 Interim Report* (see Attachment I).

2.2.2 Variable Air Volume (VAV) System Static Pressure Reset and Discharge Air Regulation Technique (DART) for Constant Volume (CV) to VAV System Conversion

Federspiel Controls developed SAV with InCITe™—a variable air volume (VAV) static pressure reset system—and the Discharge Air Regulation Technique (DART) as part of its Energy Innovation Small Grants (EISG) program funding (Federspiel and Clark 2002). The SAV with InCITe static pressure reset strategy was combined with DART and is no longer is supported separately.

The DART product employs wireless control technology and can be used to achieve a low-cost conversion from constant-volume HVAC systems to more efficient partial VAV operation. Demonstrations of these technologies indicate that one-quarter of fan energy can be eliminated with a one- to five-year simple payback.

2.2.3 Large Duct System Sealing

Utility funding pooled through CIEE supported Dr. Mark Modera's original work at LBNL to develop an aerosol duct sealing technology. PIER funding later supported work on commercial building applications. Forced air duct systems often leak by 20 percent or more, contributing to both thermal losses in unconditioned space and wasted fan power, which combined account for dramatic inefficiencies. Aerosol sealing is a quick method to seal even relatively large leaks in

ductwork without requiring demolition and renovation, or even identification of leak locations. Leaks are sealed while a duct system is pressurized with all registers and outlets blocked so that any flow escapes through cracks, holes and gaps. Aerosol glue is injected into the pressurized system, suspended in the low-velocity flow without coating interior duct surfaces, then deposited at leaks where momentum and turbulence causes particles to impact walls and edges and nucleate into a seal. The technology is licensed to Aeroseal.

2.2.4 Demand Controlled Kitchen Ventilation

This technology evolved from studies and code change efforts lead by the California Food Service Technology Center (FSTC) sponsored by Pacific Gas and Electric (PG&E). Because of its promise, it was included in the demonstration portfolio as an exception with only peripheral previous PIER involvement. The Melink Inteli-Hood controls system controls the ventilation rate by measuring the temperature in the exhaust duct and the containment and capture of the ventilation hood. Thus in the normal loads, the ventilation is roughly one-half of full power. Please see Chapter 4 for information about demonstrations.

2.2.5 Advanced Variable Air Volume Design Guide

The New Buildings Institute led the Integrated Energy Systems—Productivity and Building Science PIER program that included development of the *Advanced Variable Air Volume System Design Guide* (Hydeman et al 2003). A team including Taylor Engineering and Eley Associates produced the guide, which was later published in a version targeted toward Capital Program project managers in the UC and CSU systems.

2.2.6 HVAC Diagnostics

The Architectural Energy Corporation developed automated HVAC fault detection and diagnostics software with the support of the PIER program. Marketed as its ENFORMA building diagnostics product, this technology uses data form an existing building automation system (BAS) to continuously and automatically identify HVAC energy inefficiencies. Currently, the New Buildings Institute is conducting research on the status and need for code requirements for fault detection and diagnostic tools in rooftop package air conditioners.

A range of devices in this field are emerging or market available; they include both permanently installed and one-time-measurement tools, and they range from data loggers and controllers with alarm capabilities to integrated devices with strategically developed algorithms for fault detection and diagnostics. Some noteworthy tools include:

- Field Diagnostics HVAC Service Assistant
- ClimaCheck
- PowerMand DreamWatts
- EZESys
- NorthWrite Energy Expert
- Virtjoule
- Pacific Northwest National Laboratory Smart Monitoring Diagnostic System

Though these products have not been directly developed by PIER, research by PIER in this general area has led to interest in this technology and a large scale field demonstration of a commercial program offering featuring one of the products (please see Chapter 4 for details).

2.2.7 Hybrid Rooftop Packaged Air Conditioners

With PIER support the UC Davis Western Cooling Efficiency Center (WCEC) hosts the Western Cooling Challenge, a program that invites HVAC manufacturers to design and commercialize the next generation of rooftop packaged air conditioning equipment that achieve at least 40 percent energy savings and demand reduction compared to 2010 DOE standards. Currently each entry to the Cooling Challenge is configured differently, though all are hybrid systems that use indirect and/or direct evaporative cooling in combination with high efficiency vapor-compression to maintain capacity under all conditions required by the program. The Coolerado H80 is the first equipment to receive certification; laboratory testing suggests that the system could achieve 50 to 80 percent energy savings compared to standard equipment. Manufacturers engaged in the Cooling Challenge with emerging or market available technologies include:

- Coolerado.
- Munters DesChamps.
- Seeley.
- York.
- Trane.
- Integrated Comfort.
- Speakman.

2.2.8 Occupancy-Based Control

The Program also explored new HVAC control technology in applications provided by the UC Merced campus test bed. UC Merced investigated the use of low-resolution video camera technology for occupancy sensing with building control applications.

2.2.9 Chiller Optimization

Lawrence Berkeley National Laboratory explored the use of chiller optimization algorithms to a campus chiller plant, district-cooling system, and chilled water thermal energy storage tank.

2.3 Building Energy Management

The program showcased PIER building energy management technologies, including:

- The Information, Monitoring, and Diagnostic System (IMDS) in the form of Monitoring-Based Commissioning).
- Benchmarking.
- (Building) Performance Visualization.
- Energy Information Systems.

The subsections below summarize the building energy management technologies demonstrated.

2.3.1 Monitoring-Based Commissioning (MBCx)

Mary Ann Piette and colleagues at LBNL explored the Information, Monitoring, and Diagnostic System (IMDS) technology in the 1990s, with initial funding by CIEE for the pilot site at 920 Sansome Street in San Francisco. PIER funded the second pilot site at 925 L Street in Sacramento. The IMDS was adapted by CIEE to a monitoring-based retro-commissioning approach—for deployment in an IOU partnership with the University of California and California State University systems using California Public Utilities Commission-administered public goods energy efficiency deployment funding.

In 2003, CIEE worked with the University of California Office of the President to propose monitoring-based commissioning as a major element of the UC/CSU/IOU Energy Efficiency Partnership. The partnership was initiated in the 2004–2005 cycle of energy efficiency deployment funding administered by the California Public Utilities Commission.

The 2004–2005 UC/CSU/IOU Partnership Monitoring-Based Commissioning (MBCx) Program is a successful pilot implementation of the IMDS approach at scale in a mainstream energy efficiency program deployment. The SPEED program provided technical support to the Partnership, as described in Chapter 4.

2.3.2 Benchmarking

The SPEED program also called on PIER-funded researchers at LBNL to apply benchmarking approaches to enhance the UC/CSU/IOU Energy Efficiency Partnership MBCx program element, as described in Chapter 4.

2.3.3 Building Performance Visualization

Lawrence Berkeley National Lab prototyped building performance visualization tools for a UC Merced building. This field research project was initiated within the SPEED program to take advantage of U.S. Department of Energy co-funding and United Technologies Research Center in-kind support. This technology includes data-mining software, building performance metrics, and a "dashboard" capability. The system was migrated to the UC Merced campus for use by campus energy management personnel, as described in Chapter 4.

2.3.4 Energy Information Systems

Lawrence Berkeley National Lab also initiated documentation of the state-of-the-art for *Web-Based Energy Information Systems for Energy Management and Demand Response in Commercial Buildings Technology* (Selkowitz 2003b) as a part of its PIER-funded High Performance Commercial Building Systems program. This report, including new case studies, was updated as described in Chapter 4.

2.4 Other

The SPEED Program has showcased PIER Industrial Agriculture and Water (IAW) Program technologies, including:

- Datacenter Automation Software and Hardware (DASH or DART for Datacenters)
- IT Temperature Sensors for Datacenter HVAC Control

- Liquid Cooled Servers
- Centralized Demand Controlled Ventilation (for Laboratories)

The Program also initiated a project to apply industrial-derived Energy Information System (EIS) technology in the building energy management context; however, this project was discontinued due to lack of progress. In addition, the program developed a project to demonstrate laboratory fume hood sash controls, but this project was not pursued because anticipated utility co-funding did not materialize.

The subsections below summarize the IAW products demonstrated; please see Chapter 4 for more detailed summary information on demonstration projects. Further details of the IAW area technology demonstrations can be found in Technical Reports (see Attachment III).

2.4.1 Datacenter Automation Software and Hardware (DASH)

Federspiel Controls derived the Data Center Automation Software and Hardware (DASH) technology from the Discharge Air Regulation Technique (DART) technology demonstrated on building HVAC systems (see Section 2.2.2).

Typical data centers use server equipment that cannot operate in high temperatures, and data center cooling and computing components use low-efficiency, single-speed fans that cannot dynamically shift cool air to where it is most needed. This project integrates variable-speed fans, adjustable server fan inlets, and wireless temperature sensors to continuously adjust cool air volume and its targets, according to temperature requirements. The technology can be supplemented with curtains to direct cooling where needed. Fusible link hangers allow the curtains to meet fire protection standards. This strategy can significantly reduce a datacenter's cooling infrastructure, which typically consumes 25 percent of the facility's electrical energy.

2.4.2 IT Temperature Sensors for Datacenter HVAC Control

Lawrence Berkeley National Laboratory explored the use of IT temperature sensors for datacenter HVAC Control through the SPEED program. This is a variation on the general approach employed by the DASH technology (see Section 2.4.1). This approach uses the front-panel temperature sensor data from the Information and Communications Technology (ICT) Management Network to control the facility management system (FMS) to make control of cooling devices more effective.

2.4.3 Liquid-Cooled Servers

The Clustered Systems Company developed heat exchange technology to enhance the performance of liquid cooled server systems as a PIER EISG project. (Hughes 2008).

2.4.4 Centralized Demand Controlled Ventilation (for Laboratories)

Lawrence Berkeley National Lab originally investigated centralized demand controlled ventilation as a part of its work on laboratory energy efficiency. This technology can reduce laboratory HVAC energy use by as much as 50 percent by employing high ventilation rates only when significant air contaminants are detected. (This is one of the exceptions in the demonstration portfolio where the technology was not directly developed by PIER research,

development, and demonstration activities). Please see Chapter 4 for details of the demonstration project for this technology.

CHAPTER 3: Program Partners

3.1 Original Partners

The program's first three years focused on demonstration sites within the University of California and California State University systems. In addition, the program partnered with the New York State Energy Research and Development Authority (NYSERDA) and the National Electrical Manufacturers Association (NEMA), two groups similarly interested in development and demonstration of energy-efficient building technologies.

3.1.1 University of California/California State University System

In 2004, UC, CSU, and California investor-owned utilities (IOUs) formed the statewide UC/CSU/IOU Energy Efficiency Partnership ("The Partnership") and received funding from the California Public Utilities Commission (CPUC) for a wide variety of projects to increase the efficiency of university facilities. The Partnership consisted of three elements: (1) conventional retrofit projects, (2) an innovative monitoring-based commissioning element partially based on CIEE and PIER-funded R&D, and (3) a Partnership training and education (T&E) team to create and deliver a T&E program to higher education staff.

During the same period, the California Energy Commission's Public Interest Energy Research (PIER) program created the Energy Efficient Campuses Program (since renamed the SPEED Program) to apply PIER products and results at California campuses to increase energy efficiency. PIER team members began to work directly with the campuses and with the partnership to combine the mutual objectives and opportunities of the two programs.

Since 2002, the PIER program has focused on research that leads directly to market-ready applications of products and information. The program has an extensive array of new products, guidelines, and data that can significantly improve the efficiency and operations of buildings.

PIER has strongly supported all three elements of the partnership.

All UC and CSU campuses are eligible to participate in the program. The demonstrations are intended to prove the merits and promote the adoption of lighting technologies on campuses throughout the UC and CSU systems. Technical experts install the technologies on campuses, and facilities managers receive training, support, and participation to maximize the technologies' benefits.

3.1.2 National Electrical Manufacturers Association (NEMA)

The National Electrical Manufacturers Association provided funds to help CLTC start as a research and design facility. It also helped develop the open digital communication protocol for complete lighting systems with the California Energy Commission. This preliminary work on an enhanced digital addressable lighting interface (DALI) ballast control standard led to additions and modifications to the NEMA draft standard, which resulted in an additional

partnership with the Energy Commission to validate the standard as part of the PIER Demonstration program.

Some funding from the SPEED program contributed to a demonstration at UC Davis.

3.1.3 New York State Energy Research and Development Authority (NYSERDA)

The New York State Energy Research and Development Authority and the PIER Program demonstrated a bi-level smart stairwell luminaire that uses an ultrasonic occupancy sensor to detect motion. NYSERDA and PIER researchers also developed a low-cost, load-shed ballast and control system, called the *Sylvania Powershed,* to trim lighting power and lighting levels. Finally, NYSERDA, along with the California Energy Commission, helped fund demonstrations for the Integrated Classroom Lighting System.

3.1.4 Northwest Energy Efficiency Alliance and California Statewide Savings By Design Program

The Northwest Energy Efficiency Alliance provided funding for the enhancements for the 3.0 version of the Sensor Placement and Optimizing Tool (SPOT) in 2006. The California IOU statewide Savings by Design Program's educational service "Energy Design Resources" program cofounding for the enhancements for version 4.0 of SPOT in 2008 and 2009.

3.2 SPEED Expands – New Partners

3.2.1 California Community Colleges

Beginning in late 2007, the program began demonstration activities with the California Community Colleges (CCC). The CCCs are organized into thirteen districts, each with its own planning, capital improvements, and facilities structure. Several colleges showed high interest in participating in the program, including Butte Community College in Oroville; Citrus College in Glendale; Cypress College in Cypress, and Southwestern College in Chula Vista. Demonstrations were conducted on these four campuses in 2007-2008. Demonstrations were also organized at Los Angeles Trade-Technical College when this campus became the site of the 2010 California Higher Education Sustainability Conference.

3.2.2 California Department of General Services

The State of California is one of the largest building owners in the State. The DGS operates a broad range of structures for the State of California, and they run the gamut from multi-story offices to garages and warehouses. The program is working closely with DGS to identify energy efficient demonstration projects that would fit within the financial programmatic and financial constraints of the California State system. The program was able to complete an initial set of demonstrations, and recommendations were provided for widespread implementation of several key technologies, including bi-level parking garage lighting and task/ambient office lighting.

Demonstrations were conducted in facilities of the following state agencies:

- California Department of Parks and Recreation
- California Department of Public Health

- California Franchise Tax Board
- California Energy Commission
- Ziggurat Building (DGS)

3.2.3 Cities, Counties, and Special Districts

The Energy Commission project manager requested that the program expand to include local governments and special districts as potential hosts of PIER technology demonstrations. The program explored potential project with the following local government entities:

- Sacramento (Arcade Creek) Regional Parks
- City of San Marcos
- County of San Luis Obispo
- City of Huntington Beach
- City of Santa Monica

The Program developed a smart (bi-level) LED bollard project with the Sacramento (Arcade Creek) Parks District in collaboration with SMUD. The Program developed a demonstration of bi-level LED parking garage fixtures with the City of San Marcos. The City of San Marcos project is carrying over to the next Work Authorization.

3.2.4 Federal Facilities and California National Guard

The Energy Commission project manager requested that the program expand to include federal facilities and the California National Guard as potential host of Program demonstrations. The Program planned and organized a co-funded Integrated Office Lighting System (IOLS at the National Guard headquarters in Sacramento. This will be implemented in August 2010 as a carryover project. This working relationship led to a joint effort by CLTC and Southern California Edison (SCE) to recommend LED runway lighting efficiency improvements for a pilot project. In addition, CLTC received additional funding in June 2010 to survey and recommend a lighting efficiency improvement for the National Guard armories, including the smart exterior lighting as well as the interior lighting technologies.

Some preliminary project scoping has been done for several military bases. Site visits to Beale Air Force base for preliminary lighting audits and recommendations were made in 2009, and these may lead to substantial future projects. Meetings have also been held regarding Navy facilities in San Diego. These facilities may use several PIER technologies in their lighting retrofits.

3.2.5 Private Companies

The Program expanded to include private companies as demonstration sites in conjunction with an effort to work with Silicon Valley Leadership Group organizations and the inclusion of PIER Industrial Agriculture/Water End-Use Efficiency Area technologies in the demonstration portfolio. Intel hosted a demonstration of the use of information technology equipment sensors for computer room temperature control and Sun Microsystems hosted testing of liquid-cooled server technology (see Attachment III—Technical Reports).

3.2.6 Utility Emerging Technology Projects

The demonstration activities completed by the Program typically feed directly into activities conducted as part of the California utility Emerging Technology (ET) Programs. The ET programs seek to evaluate emerging lighting products and practices, develop energy savings profiles, and fully vet the technologies for possible inclusion in utility rebate and incentive programs.

Program demonstrations and information dissemination activities are targeted to a general audience and include a wide range of technology transfer tools. While Program demonstrations and information dissemination activities are usually sufficient to facilitate adoption by individual end-users or by leading-edge implementation programs such as the IOU Partnerships, the additional ET program vetting is necessary for inclusion of technology in standard utility incentive programs.

Collaboration with ET programs can sometimes enable advanced consideration for valuable incentive programs, resulting in accelerated market adoption. Specific examples of these unique partnerships are described in Section 6.3.2 Utility Emerging Technology Demonstrations.

Another scenario for collaboration with ET programs occurs when the demonstration project is of a scale or technical scope that is beyond the capabilities or resources of the individual programs. An example is the zero-net energy retrofit of the UC Santa Barbara Recreation Center, described in Section 6.3.2.

CHAPTER 4: Demonstrations

In 2004, the program initially focused on the institutional and educational parts of the commercial market sector, with UC and CSU system campuses as the potential demonstration hosts. These organizations were simultaneously participating in an energy-efficiency partnership with the investor-owned utilities (IOU) and developing strong policy goals for energy efficiency. (Please see Chapter 3 for additional information about the UC/CSU/IOU Energy Efficiency Partnership and the concurrent partnership with the PIER program for demonstrations.)

The program developed a procedure to engage the campuses in the initial demonstration project selection process, soliciting interest from the campuses about which technologies they would like to have installed and tested at their facilities. The program team created a packet of information consisting of a program overview, technology descriptions, and an application for campuses to request participation in the Program. The packets were distributed to energy managers and facility managers at all UC and CSU campuses.

The program overview document announced the program to the campuses and provided them with information they needed to understand its purpose and the available opportunity. The application form was designed so that the campuses could easily identify themselves, select a technology they were interested in, and provide the information that reviewers would need to decide if the campus proposed a good project. All program documents included the PIER, CIEE, UC, and CSU logos so that campus decision makers understood that the Program had broad support, and any of these organizations could be contacted to answer questions or distribute further information.

Applications were returned to CIEE, which coordinated with managers at both UC and CSU to complete a first cut at reviewing the applications and matching technologies with schools. Distribution of technologies between UC and CSU campuses, and equity within each of these systems, were key considerations in making the final decisions about which technologies to demonstrate and what campuses would serve as hosts. (Please see *PIER Energy Efficient Campuses Demonstration Program: 2004-2007 Interim Report* in Attachment I for more details regarding the selection process.) For this first set of demonstrations in 2004–2007, the Program covered virtually all costs, including retrofit installation.

The program shifted to a more informal project selection process with the addition of several more target markets and a much wider range of potential host organizations in 2007. A steering group for a new California Community College/IOU Energy Efficiency Partnership identified potential host CCC campuses. PIER Buildings and IAW End-Use Efficiency area personnel identified candidate host organizations from among numerous state agencies and Silicon Valley Leadership Group organizations. In addition, the PIER project manager added local governments, special districts, and California National Guard facilities to the scope of the

program, identifying potential host sites in these sectors. Cost sharing of demonstrations became more important to the program in 2007–2010 (see Section 4.5).

The 2004–2010 Program developed a portfolio of over one hundred projects; including demonstrations, field research projects, and special technology transfer projects. Around ten of the projects were carried over for completion in the 2010–2011 phase of the Program. Please see Section 4.2 for a tabulation of all projects.

The demonstration projects themselves resulted in substantial energy savings (see Table 1 in Section 4.2.5). However, the full potential opportunity for PIER technologies lies in their market potential (see Tables 2 and 3 in Section 4.4). This Program is helping to capture that value through market transformation enabled by its demonstrations, and through special technology transfer projects and other outreach. Progress toward potential market penetration is illustrated by the extensive use of the demonstrated technologies in mainstream energy efficiency deployment programs (see Section 4.4.1 and Table 4).

4.1 Demonstration Project Process

The typical demonstration project process began with the matching of technologies with a host site. Program team members typically produced a project brief for review by host site personnel. Upon approval of the project by site personnel, a more extensive site survey was usually conducted to produce detailed engineering information for the retrofit and monitoring requirements.

Following review of detailed project information by site personnel, pre-retrofit monitoring was installed and data were collected for parameters appropriate to the technology and site conditions. The pre-retrofit data collection period varied, commensurate with the accuracy and precision needed for the specific technology. Fabrication of the retrofit was procured using appropriate methods, with materials and/or installation often provided in-kind by the host site in the later years of the Program (2007–2010). The retrofit process included project commissioning, which sometimes extended to resolution of issues identified through the post-retrofit monitoring.

Following fabrication of the retrofit, post-monitoring was performed, again for parameters and a period commensurate with the technology and site. Once an adequate period of satisfactory operation produced the necessary data, data analysis was performed to establish site-specific technology performance. The technology performance was then evaluated in collaboration with site personnel, with the results typically documented in a case study.

Case studies and other project information tools were developed to help the host site, sister campuses or organizations, or organizations-at-large consider use of the technology in their applications. Technology performance information may be extrapolated to other potential site conditions with typical statewide energy prices, typical site conditions, or conditions typical for a specific deployment program targeted for technology transfer (for example, the UC/CSU/IOU Partnership). Demonstration performance information may also be used as feedback to the RD&D process, which may include a derivative product development process.

The Program also developed field research projects and technology transfer projects supporting specific deployment programs. The development process was different from typical demonstrations and unique for each of these special projects. For more information on these projects, please see Section 4.2 and Attachment III—Technical Reports.

4.1.1 Matching Technologies With Host Sites

The first program demonstration projects identified appropriate technologies through a solicitation process involving all potential candidate UC and CSU campuses (see the beginning of this section). Subsequent demonstration projects identified appropriate technologies through an iterative consultative process with Energy Commission managers, steering group members, and potential host organizations. Site visits, review of utility usage information, and review of as-built drawings were conducted for potential host sites.

Matching appropriate technologies with host sites was a key to the broader success of the program, as well as to the success of individual demonstrations. The needs and capabilities of the host organization needed to be aligned with program resources and planning. The level of interest of the host organization had to be matched to the needs of the program. The technical capabilities and leadership potential of the host organization needed to be appropriate for the stage of market adoption of the technology. More progressive and technically capable organizations helped more with newer technology. Organizations taking a leadership role in their market sector helped when perceived barriers were an issue. The representative nature of host buildings helped make demonstration case studies more widely applicable. Level of visibility was another important factor, as was the use of California Higher Education Sustainability Conference hosts as sites for clusters of multiple demonstrations. Finally, the ability of the host organization to support the project with in-kind resources, including installation and procurement of materials, was important, especially for HVAC or other more expensive technologies.

The provision of applicable information about the selected technology to host sites was critical in gaining buy-in and facilitating the demonstration process.

4.1.2 Demonstration Project Planning

Initial information about the proposed demonstration was typically provided to the host site in a project brief. The brief typically included documentation of existing site conditions relevant to the proposed technology, a description of the proposed technology, prediction of post-retrofit performance improvements and/or energy savings, and a monitoring plan.

A more extensive site survey followed host site approval of the project. This more detailed survey typically provided information for engineering of the retrofit and the monitoring. Pre-retrofit monitoring was initiated after host site review of the retrofit and monitoring plans.

4.1.3 Monitoring Methodology

Pre- and post-retrofit technology demonstration site monitoring was essential for understanding how building technologies were actually being used, for measuring energy performance, and for documenting perceptions of energy managers and occupants about the overall performance of new technologies.

Each technology had different monitoring needs. To determine the success of the technologies, various performance parameters needed to be measured or otherwise determined, both for a baseline period before the technology was installed and after installation. New technology benefits include reductions in energy usage and/or demand, improvements in equipment performance, improved lighting quality, air quality for building or area occupants, and/or enhanced ability for facilities personnel to monitor equipment operation and detect degrading performance.

With these considerations in mind, performance measurements were made before and after the technology installations. The pre-retrofit measurements served as a baseline to which the post-retrofit measurements were compared. For most lighting products, the comparisons of performance before and after the retrofits was relatively straightforward, and a two-week monitoring period was usually enough time to capture either pre- or post-retrofit performance.

These comparisons were not as simple for some non-lighting technologies. For example, additional monitoring periods were desirable to capture both warm- and cool-weather performance measurements for some HVAC technologies, such as the Discharge Air Regulation Technique (DART). More than two weeks of pre-retrofit and post-retrofit data were often also needed for cases with atypical weather during the monitoring period. This information was used to extrapolate annual energy savings for monitored campuses, as well as to estimate statewide savings in the event of large-scale technology implementation. Some monitoring remained installed for a protracted length of time, to collect usage data during and between academic terms on higher education campuses. This included holiday usage patterns as well as those during summer breaks. Weekends were included in the data sets.

Pro-forma research plans were typically drafted for each of the technologies, stating the major unknowns about the technology, what the monitored points should be, and what analysis would be performed.

4.1.3.1 Preretrofit Monitoring Sequence

The performance of existing systems was evaluated before they were replaced by the PIER technologies. The pre-retrofit performance evaluation activities were tailored to the technology and the campus. In general, the following activities were performed.

- **Adapt the Performance Evaluation Plan for Each Technology and Campus.** Plans were adapted for specific circumstances that arose at the campus or that arose because new information became available about the technologies.
- **Identify and Obtain Data Acquisition System (DAS) Equipment.** In some cases data could be trended using existing energy management and control systems (EMCS). In most cases, however, data acquisition equipment was in the inventory of a Program team member, purchased, or leased.
- **Install DAS.** The necessary data acquisition equipment was installed at each campus. The project team worked with campus personnel and/or appropriately sourced local technicians, if necessary, to perform the installations.

- **Perform One-Time Tests.** One-time tests of equipment are often conducted, as called for in the Performance Evaluation Plan. For non-lighting equipment, this sometimes includes estimates of duct leakage or airflow rates.
- **Collect Data.** Pre-retrofit time-series data were collected for an appropriate time period before the PIER technologies were installed. Data were downloaded prior to retrofit for preliminary analysis, and the monitoring equipment left in place.
- **Preliminary Analysis.** The pre-retrofit data are analyzed to develop the required performance metrics. If problems with the data were identified during the analysis process, additional data were collected, as necessary, to obtain satisfactory results.

Program team members performed many of the monitoring tasks. Appropriately sourced local technicians were also used for monitoring tasks, particularly at Southern California demonstration sites.

4.1.3.2 One-Time Tests

When possible, existing energy management and control systems (EMCS) were used to determine baseline energy consumption, including peak power demand. However, supplementary instrumentation was often required. Prior to the pre-retrofit logging period, a portable power meter was typically used to measure the instantaneous voltage, current, power, and power factor consumption of each system being retrofit. Typical instrumentation used for this purpose was a FLUKE Power Quality Analyzer or a Powersight 3000 Power Meter.

Where appropriate, measurements were taken at both the lighting fixture location and the electrical panels. One reason for these preliminary measurements was to ensure that the correct data logging equipment (in particular, current transducers) could be chosen.

The portable power meters were also often used to study the harmonics in the voltage waveforms, particularly from variable speed drives. This was necessary because some current transducers were found to be sensitive to voltage harmonics. During the course of the project some of the power instrumentation used to monitor motors with variable speed drives was modified to work properly in this application.

One-time power measurements occasionally sufficed for situations in which logging was not required but a peak measurement was needed.

Illuminance measurements were also conducted for proposed lighting retrofit locations. Light level readings were collected in a manner consistent with Illuminating Engineering Society of North America (IENSA) recommended practices, typically using a Minolta T-10 illuminance meter or an Osram Sylvania DS-2050 illuminance meter.

Location and scenarios for light level measurements were technology and location specific. For bi-level stairwells fixtures, baseline readings were taken at floor level in corresponding landing and midpoint locations whenever possible. Light level readings for the ICLS were taken at desk level, as well as at several locations throughout the classroom. Readings for the ICLS were taken for multiple lighting settings such as All On, Audio/Visual (A/V) with Whiteboard On, and Whiteboard Only.

4.1.3.3 Trending Data Acquisition Systems

Pre- and post-retrofit trend monitoring usually supplemented one-time measurements. When possible, existing EMCS were used to determine baseline energy consumption trends. Other types of data logging instrumentation were also employed. Field logging systems were typically employed at the start of the Program, with follow-up visits necessary to upload data to laptop computers. A migration toward on-line and wireless data acquisition systems occurred later in the Program.

4.1.3.4 Lighting-Specific Monitoring

For many lighting technology retrofits, loggers recorded two parameters: light level and occupancy. The occupancy data was used to check the validity of the lighting data. For example, a comparison between actual fixture use and building occupancy would determine if the fixtures were on during periods of non-occupancy.

Typical types of lighting instrumentation included Watt Stopper IT-200 Intellitimer Pro data loggers and Onset Computer Company's Hobo Light Logger. These devices recorded light levels (including on/off determination) and, in certain cases, space occupancy.

Intellitimer Pro data loggers consist of an infrared occupancy sensor and a photosensor attached to a directional light pipe. This enabled orientation of the photosensor at light fixtures to determine on-off status and therefore system usage while simultaneously comparing it to actual occupancy. This duality allowed for determination of existing system usage compared to actual building occupancy. Loggers installed at the classroom installations were affixed to the ceiling using T-bar clips. All other logger installations used a double-sided foam adhesive.

Another typical device was the Hobo Light Logger manufactured by Onset Computer Company. This device contained a photosensor with adjustable sensitivity to determine fixture usage. These data loggers were employed when a motion sensor to collect space occupancy data during fixture usage was not required.

4.1.3.5 HVAC-Specific Monitoring

For earlier projects (in 2004–2008), AEC's "MicroDataLogger®" data loggers (MDLs) were often used to collect pre-retrofit data. These loggers have the ability to record data at user-determined time intervals from a variety of sensor types, such as temperature, humidity, voltage, current, static pressure, and electrical power. Another example of typical data logging equipment is WattNode™ brand power transducers. Each sensor and transducer was connected to a signal-conditioning module that converted the sensor output to a low-voltage, milliamp, or pulse signal that could be processed and recorded by the data logger. Scale factors set up in the logger through a software interface prior to installation allowed the logger to record and store actual values of information such as temperature, pressure, humidity, and watt-hours.

In particular, the MDLs enabled the project team to collect data for the Static Pressure Reset / SAV with InCITe and IAQ Damper technologies. For Static Pressure Reset / SAV with InCITe, the main variables monitored were the ambient air temperature and relative humidity, and the power requirements for the supply and return ventilation fans to which the technology was applied.

For power data, WattNode transducers were often used to monitor electrical motor energy consumption in watt-hours. The transducer sent pulses to the MDLs, which totaled and recorded them every five minutes. This technique allowed us to measure the total power consumed over the interval, rather than an instantaneous measurement that could fluctuate more rapidly, causing errors in the calculation of power.

MDLs were used to collect pre-retrofit data for all of the Supply Pressure Reset / SAV with InCITe sites included in the demonstration, except for one location when MDLs were not available. For that location, data loggers were borrowed from PG&E's Pacific Energy Center in San Francisco.

MDLs were also used to record readings from carbon dioxide (CO_2) sensors. Carbon dioxide data were helpful in evaluating air quality for the IAQ-42 damper demonstrations.

4.1.4 Retrofit Installation

Retrofit technologies were installed following appropriate monitoring and documentation of pre-retrofit conditions. Installation was performed by host site personnel or by appropriately sourced local technicians. For the first three years of the Program, materials and installation were usually fully paid for by the Program. More cost sharing for the retrofit technologies was typical for later demonstrations.

Initial commissioning was performed immediately following installation of retrofit technologies. Additional commissioning was often necessary when operational issues were discovered during post-retrofit monitoring.

4.1.5 Performance Evaluation

The performance evaluation process began with preliminary data reduction and analysis for the baseline period prior to retrofit installation. This ensured that adequate baseline data was obtained. Preliminary data reduction also laid the groundwork for and facilitated post-retrofit monitoring.

Lessons learned during the installation process also can be part of technology evaluation. Issues can include cost, trades integration, other installer feedback, and commissioning needs. Information gained can inform mainstream deployment efforts or provide feedback to derivative product development.

Evaluation continued with post-retrofit monitoring, which generally included the same data collection as that done for pre-retrofit monitoring, but was informed by lessons learned in pre-retrofit monitoring and included a few additional activities. These additional activities included additions to occupant surveys and monitoring, to include information about features unique to the new technology. For example, for technologies using occupancy sensing, monitoring was used to determine if "false-ons" were occurring or if sensors were not detecting occupants when, in fact, they should have been. Post-retrofit activities also included obtaining host site feedback and removal of temporary data acquisition equipment.

Data reduction followed, with methods varying for each technology and monitoring scenario. Data reduction tools included spreadsheets developed by Program team members, proprietary

software developed by data logger manufacturers, and software developed by technology vendors when validated by Program team members. Data diagnostic methods can vary from the graphical use of raw time series data, to standard regression analysis, to complex custom spreadsheet analyses.

4.1.5.1 Analysis

As with data reduction, the analysis method for each technology varied. In general, the data collected post-retrofit were analyzed to develop the required performance metrics. These were compared to the pre-retrofit metrics to develop savings. Limited monitoring periods were extrapolated to predict annual energy use accounting for holidays and academic calendars. Results were also generalized by making appropriate assumptions to adjust baseline energy use, to account for damaged lighting fixtures, operating anomalies, and unusual existing equipment. Average energy costs were typically used to calculate cost effectiveness, rather than marginal costs.

The three possible installation scenarios of retrofit, replacement, and new construction were typically analyzed. *Retrofit* is the replacement of an existing technology before it would normally be replaced. *Replacement* is the replacement of an existing technology that has come to the end of its useful life and has to be replaced. *New construction* includes new buildings or portions of buildings, as well as major renovations. The economics of these situations are different. In the retrofit scenario, the energy cost savings produced by the new technology had to be substantial enough to justify the entire cost of the technology and the installation costs. In the replacement scenario, the energy cost savings produced by the new technology had to be substantial enough to justify only the additional cost of the technology and any additional installation cost associated with special features of the technology. The new construction scenario was similar to the replacement scenario, though, in some cases, a cost credit could be taken if other devices, such as HVAC equipment or building structure, could be downsized, improved, or eliminated.

4.1.6 Documentation

Technology performance information developed through the demonstrations was documented in a variety of technology transfer tools, including case studies (see Attachment II), technology catalogs (see Attachment IV), guide specifications (see Attachment VI), and technical briefs, as well as fact sheets, conference presentations, and articles (see Attachment VIII). Case studies and fact sheets could include field data and performance information for a single demonstration or a compilation of information from multiple sites, depending on the audience and purpose. Guide specifications and technology catalogs also included information gained through demonstration experience. In addition, the PIER Program provided information developed through demonstrations to E Source to create technical briefs:

(www.esource.com/public/products/cec_form.asp).

Venues for articles and presentations have included the Lighting Design and Applications publication, the Greenbuild conference, the American Council for an Energy-Efficient Economy Summer Study on Energy Efficiency in Buildings, the California Higher Education

Sustainability conference, an Energy Policy Advisory Committee meeting, a Consortium for Energy Efficiency meeting and the CLTC Retrofit Forums. The Program has created custom documentation utilizing demonstration results for the UC/CSU/IOU and CCC/IOU Energy Efficiency Partnerships and other market transformation opportunities. Please see Chapter 5 for more information about demonstration documentation in technology transfer tools, and Chapter 6 for more information about market transformation venues.

4.2 Summary of Demonstrations

Figures 3 and 4 provide a summary of all demonstrations and special projects completed or in-progress by the State Partnership for Energy Efficient Demonstration Program.

Figure 1: Matrix of the Demonstrations and Special Projects Conducted by the 2004–2010 State Partnership for Energy Efficient Demonstrations (SPEED) Program: Part I—Lighting

Summary of PIER SPEED Project Portfolio 2004–2010		2004–2007 Lighting									2007–2010 Lighting											
Part I - Lighting		Interior							Ext.		Interior					Exterior (Ext.)						
		Bi-Level Stairwell Lighting	Integrated Classroom Lighting System	Bathroom Smart Fixture & Switch	Energy Efficient Downlights (CFL)	Personal / Integrated Office Lighting System	Load Shed Ballast	Digital Addressable Lighting Interface (DALI)	Low-Glare Outdoor Luminaire	Smart Wall Pack Lighting	Bi-Level Stairwell Lighting Derivatives	Integrated Classroom Lighting System Derivatives	Energy Efficient Downlights (LED)	Wireless Lighting Controls	Simplified Daylighting Control (with 3-way Switching)	Smart Wall Pack Lighting (2007–2010)	Smart LED Bollards	Smart (Bi-Level) Garage Fixtures (Fluorescent)	Smart (Bi-Level) Garage Fixtures (Induction)	Smart (Bi-Level) Garage Fixtures (LED)	Smart (Bi-Level) Parking Lot/Pole Fixtures (Induction)	Smart (Bi-Level) Parking Lot/Pole Fixtures (LED)
California State University (CSU) Campuses	Chico																					
	Northridge																					
	Pomona																					
	Sacramento State																			N		
	San Diego State																					
	San Francisco State																					
	San Marcos		2		P																	
	Sonoma State	P	P	N																		
	Stanislaus																					
	2008 Conference—SLO			N													N				N	N
University of California (UC) Campuses	Office of the President																					
	Davis	C		2										C					N			N
	Irvine																					
	Los Angeles																					
	Riverside																					
	San Diego																					
	San Francisco																				2	
	Santa Barbara (SB)																					
	2007 Conference—SB																					
	2009 Conference—SB												N		N			N	N	N	N	N
UC/CSU	IOU Partnership	G																				
Community Colleges	Butte																					
	Citrus																					
	Cypress																					
	Southwestern																					
	2010 Conference—LATTC										C	C									C	C
State Agencies	Energy Commission																					
	DGS Ziggurat (with PG&E)																					
	DGS Garages (multiple sites)																	Surveys				
	CDPH Richmond																					
	Parks																					
Special Sites	Sacramento Parks																					
	CA National Guard Sacramento					C																
	City of San Marcos																			C		

C	Carryover to 2010–2011	LATTC	Los Angeles Trade-Technical College	2	2 Different Projects
CA	California	LED	Light Emitting Diode		2004–2007
CDP	CA Department of Public Health	N	Non-State (Auxiliary) Facilities		2007–2010
CFL	Compact Fluorescent Lamp	P	Capital Projects		
DGS	Department of General Services	PG&E	Pacific Gas and Electric		
G	Group Purchase	SLO	San Luis Obispo		

Figure 2: Matrix of the Demonstrations and Special Projects Conducted by the 2004-2010 SPEED Program: Part II—HVAC and Other Non-Lighting Projects

Summary of PIER SPEED Project Portfolio 2004–2010			2004–2007								2007–2010									
Part II—HVAC and Other Non-Lighting Projects			HVAC					EM			HVAC			EM			IAW			
Working Draft 18 December 2010		Multiple Technology Deployment Program Assistance	Kitchen Hood Demand Control Ventilation	Static Pressure Reset and DART VAV Conversion	HVAC Diagnostics	Large Duct System Sealing	Air Flow Measurement and Control (IAQ-62)	Application Study: VAV Design Guide	Program Assistance: Monitoring-Based Commissioning	Program Assistance: Benchmarking	Hybrid Rooftop Package Air Conditioners	HVAC Diagnostics	Field Research: Occupancy-Based Control	Field Research: Chiller Optimization	Alpha Test: Performance Visualization	Technology Survey: Energy Information Systems	Data Center Automation Software and Hardware	Alpha Test: Using IT Temperature Sensors for Data Center HVAC Control	Alpha Test: Liquid Cooled Servers	Beta Test: Centralized Demand Controlled Ventilation (Labs)
California State University (CSU) Campuses	East Bay																			
	Stanislaus																			
	2008 Conference—SLO		N																	
University of California (UC) Campuses	Office of the President																			
	Berkeley		N																	
	Davis										C	C								
	Irvine																			
	Los Angeles		N																	
	Merced							N												
	San Diego																			
	Santa Barbara (SB)																			
	2007 Conference—SB		N																	
UC/CSU	IOU Partnership	T																		
Community Colleges	Butte		N																	
State Agencies	California Franchise Tax Board																			
SVLG Organizations	Intel Corporation																			
	Sun Microsystems																			
All Sectors	Special Technology Transfer	M																		

C	Carryover to 2010–2011	M	Municipal and Commercial Building Targeted Measure Retrofit Program
CA	California		
DART	Discharge Air Regulation Technique	N	Non-State (Auxiliary) Facilities
EM	Energy Management	SLO	San Luis Obispo
HVAC	Heating, Ventilation, and Air Conditioning	SVLG	Silicon Valley Leadership Group
IAQ	Indoor Air Quality	T	Training and Education
IAW	Industrial, Agriculture, and Water Area	VAV	Variable Air Volume
IT	Information Technology		2004–2007
			2007–2010

4.3 Details of Demonstrations

4.3.1 Lighting

From 2004 through 2010, the Program and CLTC, in partnership with host sites across California, organized installation of more than one thousand energy-efficient lighting fixtures and other products in dozens of demonstration installations. (The group purchase of the bi-level stairwell fixture organized for multiple UC campuses added more than one thousand more fixtures to the total organized by the program. Please see Chapter 6 for more information.). These demonstrations have laid some substantial groundwork from which other groups interested in emerging energy-efficient lighting technologies may build a case for retrofit or new construction projects that use these innovative products and practices.

The CLTC completed demonstrations with more than thirty individual host sites. Reports on these demonstration projects may be found in Attachment III—Technical Reports. In addition, information on lighting demonstrations conducted during the first three years of this program may be found in Attachment I, the *PIER Energy Efficient Campuses Demonstration Program: 2004-2007 Interim Report.*

Many of these projects resulted in PIER Demonstration case studies, which may be found in Attachment II. Energy savings from these demonstrated technologies is significant, but energy savings tell only part of the success story that is embodied by many of these technologies. A primary focus for many of the PIER lighting technologies is longevity and maintenance benefits. These benefits correlate directly to cost savings. Many of the technologies, when evaluated over the course of their useful life, offer savings well in excess of traditional lighting measures.

See Figure 31 for a summary matrix of the lighting demonstrations and projects conducted by the Program.

4.3.2 Heating, Ventilation, and Air Conditioning

See Figure 4 for a summary matrix of Heating Ventilation and Air Conditioning demonstrations and projects conducted by the Program.

4.3.2.1 Variable Air Volume System Static Pressure Reset and Discharge Air Regulation Technique (DART)

The Program demonstrated Federspiel Controls HVAC controls technologies, first as the SAV with InCITE™ variable air volume system static pressure reset product, and later as the Discharge Air Regulation Technique (DART) product (see Attachment II—Case Studies). The DART demonstrations included the sites of both the 2008 and 2009 California Higher Education Sustainability conferences at UC Santa Barbara and Cal Poly San Luis Obispo, respectively.

4.3.2.2 Demand-Controlled Kitchen Ventilation

The Program retrofitted and monitored five different demand controlled commercial kitchen ventilation systems. It also partnered with the Sacramento Municipal Utility District (SMUD) on their project with Sacramento Community College. The Sacramento CC and Butte College projects were combined in one case study. The demonstrations confirm the savings produced

by this technology are substantial and indicate that this is a strategy worth considering for all kitchen ventilation systems that have long hours of operation and large fan motors. Nomographs in the case studies created for this technology predict savings based on hours of operation and fan horsepower (see Attachment II—Case Studies).

4.3.2.3 Large System Duct Sealing—Aerosol Duct Sealing for Central Exhaust Ventilation

The Western Cooling Efficiency Center conducted a demonstration of the Aerosol duct sealing technology developed by Dr. Mark Modera at Lawrence Berkeley National Laboratory. The leak sealing technique had been well vetted for residential duct systems and for supply and return air systems in commercial HVAC; this demonstration applied the technology in central exhaust ventilation. With significant cost sharing from UC Davis Student Housing, Aerosol was installed in three multistory residence halls with exhaust systems that measured 20 to 30 percent leakage. Due to sealing, ventilation flow increased dramatically and it was determined that existing fans could be replaced with smaller, lower-flow fans that consume 50 percent less electricity. In addition, the reduced exhaust flow is estimated to reduce energy use for heating and cooling by at least 20 percent. See Attachment II—Case Studies.

4.3.2.4 HVAC Fault Detection and Diagnostic Tools

The automated HVAC fault detection and diagnosis software marketed by Architectural Energy Corporation as ENFORMA was demonstrated at UC and CSU sites, including the demonstration cluster at the 2008 California Higher Education Sustainability conference at Cal Poly San Luis Obispo. See Attachment II—Case Studies.

The Program is demonstrating Air Care Plus™, an enhanced maintenance program for vapor compression air conditioning equipment at UC Davis. The system uses the Field Diagnostics Service Assistant™ to identify inefficiencies in a system and determine the appropriate adjustments that should be made to improve performance. This technology is one of the exceptions in the demonstration portfolio not developed directly by PIER. However PIER has funded general R&D in this area. This demonstration will carry over to the next phase of the program.

4.3.2.5 Hybrid Rooftop Package Air Conditioners

The Program has initiated demonstrations of the Coolerado H80 hybrid rooftop package air conditioner, the first to receive certification in conjunction with the Western Cooling Challenge. One unit will be installed at UC Davis. The Los Angeles Community College District was slated to be the site for the other installation, but has not identified a host campus. Another host organization is being sought. These demonstrations will carry over to the next phase of the Program.

4.3.2.6 Chiller Plant Optimization

The SPEED Program, the U.S. Department of Energy, and United Technologies Research Center co-funded development and alpha testing of a Chiller Plant Optimization algorithm at UC Merced. See Attachment III—Technical Reports.

4.3.2.7 Occupancy Sensing

The SPEED Program, the U.S. Department of Energy, and United Technologies Research Center co-funded field research on occupancy sensing using low-resolution video technology at UC Merced. See Attachment III—Technical Reports.

4.3.2.8 Advanced Variable Air Volume Design Guide

The SPEED Program funded an Application Study of the use of the Advanced Variable Air Volume Design Guide. Lawrence Berkeley National Laboratory reviewed the design of the original Recreation and Wellness Center at UC Merced, assessing the degree to which the recommendations of the guide were followed. Lawrence Berkeley National Laboratory compared the energy use intensity of this facility with other similar facilities and with benchmark data. See Attachment III—Technical Reports.

4.3.3 Building Energy Management

4.3.3.1 Information Monitoring and Diagnostic System/Monitoring-Based Commissioning

The SPEED Program provided technical support to the UC/CSU/IOU Energy Efficiency Partnership in the form of two LBNL documents:

- *Monitoring Based Commissioning Needs Assessment and Case Studies* (see Attachment III—Technical Reports)
- *Monitoring Based Commissioning (Energy Information System) Architectures* (see Attachment III—Technical Reports)

4.3.3.2 Benchmarking

The SPEED Program also provided support to the UC/CSU/IOU Partnership MBCx program element in the form of a benchmarking analysis of the 2004–2005 MBCx project portfolio. Lawrence Berkeley National Laboratory researchers benchmarked the buildings that underwent monitoring-based commissioning, analyzing the relationship between building energy intensity and MBCx energy savings, as well as describing data quality control processes needed for good savings accounting. See Attachment III—Technical Reports.

4.3.3.3 Energy Information Systems (EIS)

The SPEED Program provided an update to the 2003 LBNL report *Web-Based Energy Information Systems for Energy Management and Demand Response in Commercial Buildings Technology*. This update characterized 30 energy information systems and provides four case studies of their use in a variety of organizational contexts. See Attachment III: *Building Energy Information Systems: State of the Technology and User Case Studies*.

4.3.3.4 Data Visualization

The SPEED Program, the U.S. Department of Energy, and United Technologies Research Center co-funded development and alpha testing of a data mining and data visualization tool using UC Merced monitoring data. The project initially developed the tool using archived data, and then migrated the tool to UC Merced servers for use by energy management staff. See Attachment III—Technical Reports.

The project focused mostly on Classroom and Office Building data, but is intended to help track energy use intensity benchmarks for all major buildings at UC Merced. So the project also funded diagnosis of monitoring issues for the limited district steam system serving the energy-intensive laboratory building Science and Engineering I. See Attachment III—Technical Reports.

4.3.4 Other Technologies

The SPEED Program began demonstrating technologies from the PIER Industrial/Agricultural/ Water End-Use Energy Efficiency (IAW) Program in 2007.

4.3.4.1 Data Center Automation Software and Hardware (DASH)

The SPEED Program demonstrated the Data Center Automation Software and Hardware technology at the Sacramento facility of the Franchise Tax Board. Federspiel Controls performed the demonstration of its technology with the oversight of Lawrence Berkeley National Laboratory. See Attachment III—Technical Reports.

4.3.4.2 IT Temperature Sensors for HVAC Control

The SPEED Program demonstrated IT temperature sensors for IT control at an Intel Facility. Lawrence Berkeley National Laboratory developed the approach and performed the demonstration of its technology. See Attachment III—Technical Reports.

4.3.4.3 Liquid-Cooled Servers

The SPEED Program demonstrated liquid (refrigerant) cooled server technology at a Sun Microsystems facility. The Clustered Systems Company conducted the demonstration with the oversight of LBNL as a part of the second Chill-Off Competition. See Attachment III—Technical Reports.

4.3.4.4 Centralized Demand-Controlled Ventilation

The SPEED Program field-tested centralized demand controlled ventilation technologies for wet laboratories at UC Irvine. The university conducted the testing of the Aircuity technology with the oversight of LBNL. See Attachment III—Technical Reports.

4.3.5 Savings From Demonstration Projects

The best indicators of the program's impact are the energy savings and reduced greenhouse gas footprint associated with the market potential of the demonstrated technologies. (See Section 4.3.)

However, the Program also tracks energy savings from the demonstration projects themselves. Even though the projects are generally small scale ones, the sum of the project savings is estimated to total more than $4 million over the lifecycle of the equipment—almost equivalent to the Program funding, not counting the much larger RD&D and technology transfer benefits. See Table 1 for an accounting of demonstration project direct savings. (This includes the estimated savings from the group purchase of 1,275 bi-level stairwell luminaires organized by the Program for a consortium of UC campuses.)

4.4 Market Potential of Program Technologies

The California statewide energy savings that would result from achieving the market potential of the demonstrated technologies in retrofit applications is one measure of the program's impact. Tables 2 and 3 provide high and low estimates (for 25 percent and 10 percent market penetration rates, respectively) for energy savings from a partial set of 26 of the Program technologies.

Table 1. Direct Savings From State Partnership for Energy Efficient Demonstration Program Demonstration Projects

Technology		Savings						
		Quantity Installed	Annual Electricity Saved per Unit Installed (kWh/year)	Demand Reduction (kW)	Annual Electricity Savings (kWh)	Annual Natural Gas Savings (therms /year)	Annual CO_2e Emissions Avoided (lbs.)	Annual Avoided Energy Cost ($)
Bi-Level Stairwell Luminaire	Individual Campus Demonstrations	424	353	17.1	149,782		103,350	19,472
	Group Purchase	1,275	353	51.4	450,406		310,780	58,553
Integrated Classroom Lighting System		24	3,357	18.4	80,580		55,600	10,475
Bathroom Smart Fixture		200	44	4.8	8,818		6,084	1,146
Energy Efficient Downlights	CFL	100	461	9.5	46,145		31,840	5,999
	LED	40	64	0.6	2,578		1,779	335
Load Shed Ballast		120	3	0.1	313		216	41
Digital Addressable Lighting Interface (DALI)		2	1,477	0.3	2,955		2,039	384
Integrated Office Lighting System		12	4,409	13.6	52,906		36,505	6,878
Wireless Lighting Control		10	135	0.3	1,352		933	176
Simplified Daylight Control (w 3-Way Switching)		2	741	0.3	1,483		1,023	193
Low-Glare Outdoor Luminaire		9	624		5,620		3,878	731
Bi-Level Outdoor Lighting	(HID)	14	318		4,457		3,075	579
	(Entry Way)	100	42		4,181		2,885	544
Bi-Level Bollards (LED)		17	164		2,793		1,927	363
Bi-Level Garage Fixtures	Induction	10	865	1.0	8,651		5,969	1,125
	Fluorescent	30	122	0.4	3,661		2,526	476
	LED	40	807	7.4	32,273		22,268	4,195
Bi-Level Parking Lot Fixtures	Induction Cobrahead	15	1,251		18,764		12,947	2,439
	Induction Shoebox	36	531		19,121		13,193	2,486
Bi-Level Parking Lot Fixtures	LED	34	902		30,682		21,171	3,989
	LED Post-Top	9	580	1.2	5,217		3,600	678
Lighting Totals				125.2	932,738		643,588	121,257
Static Pressure Reset		6	67,329		403,974		278,742	52,517
Discharge Air Regulation Technique		3	90,017		270,050	17,770	393,355	52,877
Large Duct System Sealing		3	6,012	1.7	18,035		12,444	2,345
HVAC Diagnostics		1	62,100		62,100		42,849	8,073
Demand Control Kitchen Ventilation		6	34,775	7.8	208,650	15,210	321,165	42.335
Data Center Automation Software and Hardware		1	339,600		339,600		234,324	44,148

HVAC Totals			9.5	1,302,409	32,980	1,282,879	202,295

Program Totals			134.7	2,235,147	32,980	1,926,467	323,552
Life Cycle Program Totals						Avoided CO_2e Emissions (lbs.)	Avoided Energy Cost ($)
						28,897,000	4,853,000

Notes:

0.69 pounds of CO_2e per kWh

11.65 pounds of CO_2e per therm

0.13 per kWh

$1.00 per therm

15-year equipment life

Table 2. Market Potential for Technologies Demonstrated by the State Partnership for Energy Efficient Demonstrations: High Estimate

PIER Technology	California Statewide Savings Potential (High Market Penetration)						
	Quantity	Annual Electricity Saved per Unit Installed (MWh)	Demand Reduction (MW)	Annual Electricity Savings (MWh)	Annual Natural Gas Savings (therms)	Annual CO_2e Savings (tons)	Annual Cost Savings ($)
Integrated Office Lighting System	1,130,000	0.71	208	801,780		276,614	104,231,400
Integrated Classroom Lighting System	89,233	2.86	109	255,577		88,174	33,225,010
Bi-level HID Wallpacks							
Bi-Level Smart Induction Shoebox							
Bi-Level Smart Induction Cobrahead							
Bi-Level Smart LED Bollard							
Bi-Level Smart LED Parking Area Luminaire							
Bi-Level Smart LED Parking Garage Luminaire			191	442,126		152,533	57,476,380
Bi-Level Smart LED Post Top Luminaire							-
Hybrid Smart Entry Luminaire							
Low Glare Wall Pack							
Bi-Level Smart Fluorescent Parking Area Luminaire							
Bi-Level Smart Induction Parking Garage Luminaire							
Bi-Level Smart Stairwell Luminaire	166,477	0.33	6	54,730		18,882	7,114,900
LED Downlights	20,723,850	0.05	509	1,065,373		367,554	138,498,490
Simplified Daylight Harvesting	113,000	0.29	8	33,117		11,425	4,305,210
Wireless control systems in commercial spaces	1,130,000	0.39	112	435,750		150,334	56,647,500
Hybrid Smart Bathroom Vanity Luminaire	30,133	0.16	1	4,874		1,682	633,620
Load Shed Ballast	2,260,000	0.29	168	656,405		226,460	85,332,650
Digitally Controllable Ballasts							
Lighting Totals			**1,312**	**3,749,732**		**1,293,658**	**487,465,160**
Coolerado H80, Hybrid Rooftop Packaged Air Conditioner (5 ton)			506	342,000		117,990	44,460,000
Aeroseal, Aerosol Duct Sealant			469	431,000		148,695	$56,030,000
Commercial Kitchen Demand Control Ventilation	3,000		23	104,325	7,605,000	80,291	21,167,250
Discharge Air Regulation Technique (DART) including SAV with inCITe savings			40	185,000	4,000,000	87,125	28,050,000
Datacenter Automation Software and Hardware (DASH)			12	205,225		70,803	26,679,250

Monitoring-Based Commissioning (MBCx)				347,500	8,678,500	170,440	53,853,500
HVAC Totals			**1,050**	**1,615,050**	**20,283,500**	**675,344**	**230,240,000**
Program Totals			**2,362**	**5,364,782**	**20,283,500**	**1,969,002**	**717,705,160**

Life Cycle Program Totals				**80,472,000**	**304,253,000**	**29,535,000**	**10,766,000,000**

Notes:

Assumed Low Retrofit Market Penetration is 10% of all commercial and institutional floor space:

Assumed High Retrofit Market Penetration is 25% of all commercial and institutional floor space

0.69 pounds of CO_2e per kWh

11.65 pounds of CO_2e per therm

0.13 per kWh

$1.00 per therm

15-year equipment life

Hybrid Rooftop Packaged Air Conditioning Unit Demonstration Not Complete (Carryover to Next Phase)

Table 3. Market Potential for Technologies Demonstrated by the State Partnership for Energy Efficient Demonstrations: Low Estimate

PIER Technology	California Statewide Savings Potential (Low Market Penetration)						
	Quantity of Systems Retrofit	Annual Electricity Saved per Unit Installed (MWh)	Demand Reduction (MW)	Annual Electricity Savings (MWh)	Annual Natural Gas Saving (therms)	Annual CO_2e Savings (tons)	Annual Cost Savings ($)
Integrated Office Lighting System	452,000	0.71	83	320,712		110,646	41,692,560
Integrated Classroom Lighting System	35,693	2.86	44	102,231		35,270	13,290,030
Bi-level HID Wallpacks							
Bi-Level Smart Induction Shoebox							
Bi-Level Smart Induction Cobrahead							
Bi-Level Smart LED Bollard							
Bi-Level Smart LED Parking Area Luminaire							
Bi-Level Smart LED Parking Garage Luminaire			77	176,850		61,013	22,990,500
Bi-Level Smart LED Post Top Luminaire							
Hybrid Smart Entry Luminaire							
Low Glare Wall Pack							
Bi-Level Smart Fluorescent Parking Area Luminaire							
Bi-Level Smart Induction Parking Garage Luminaire							
Bi-Level Smart Stairwell Luminaire	66,591	0.33	2	21,892		7,553	2,845,960
LED Downlights	8,289,540	0.05	203	426,149		147,021	55,399,370
Simplified Daylight Harvesting	45,200	0.29	3	13,247		4,570	1,722,110
Wireless control systems in commercial spaces	452,000	0.39	45	174,300		60,134	22,659,000
Hybrid Smart Bathroom Vanity Luminaire	12,053	0.16	1	1,950		673	253,500
Load Shed Ballast	904,000	0.29	67	262,562		90,584	34,133,060
Digitally Controllable Ballasts							
Lighting Totals			**525**	**1,499,893**		**517,464**	**194,986,090**
Coolerado H80, Hybrid Rooftop Packaged Air Conditioner (5 ton)			203	137,000		47,265	17,810,000
Aeroseal, Aerosol Duct Sealant			188	172,000		59,340	22,360,000
Commercial Kitchen Demand Control Ventilation	1,200		9	41,730	3,042,000	32,117	8,466,900
Discharge Air Regulation Technique (DART) including SAV with inCITe savings			16	74,000	1,600,000	34,850	11,220,000
Datacenter Automation Software and Hardware (DASH)			5	82,090		28,321	10,671,700

Monitoring-Based Commissioning (MBCx)				139,000	3,475,000	68,197	21,545,000
HVAC Totals			**421**	**645,820**	**8,117,000**	**270,090**	**92,073,600**
Program Totals			**946**	**2,145,713**	**8,117,000**	**787,554**	**287,059,690**

Life Cycle Program Totals				**32,186,000**	**121,755,000**	**11,813,000**	**4,306,000,000**

Notes:

Assumed Low Retrofit Market Penetration is 10% of all commercial and institutional floor space

Assumed High Retrofit Market Penetration is 25% of all commercial and institutional floor space

0.69 pounds of CO_2e per kWh

11.65 pounds of CO_2e per therm

$0.13 per kWh

$1.00 per therm

15-year equipment life

Hybrid Rooftop Packaged Air Conditioning Unit Demonstration Not Complete (Carryover to Next Phase)

4.4.1 Technology Deployment to Date

The energy savings targeted or achieved by major implementation programs illustrates progress toward achieving the market potential of PIER technology. Table 4 outlines annual electricity and natural gas savings for several deployment programs enabled by SPEED Program technology transfer.

Table 4. Achieved or Targeted Savings of Deployment Programs Using PIER Technologies Demonstrated by the State Partnership for Energy Efficient Demonstrations (SPEED) Program

Program	Annual Electricity Savings [1] (kWh)	Annual Natural Gas Savings [1] (therms)
Municipal and Commercial Building Targeted Measure Retrofit Program—State Energy Program/American Recovery and Reinvestment Act: Downtown Oakland Targeted Measure Saturation Program	**8,400,000**	**138,500**
Municipal and Commercial Building Targeted Measure Retrofit Program—State Energy Program/American Recovery and Reinvestment Act: Energy Technology Assistance Program	**20,700,000**	**243,200**
State Energy Program/American Recovery and Reinvestment Act: Active Management of Cooling Systems to Reduce Energy Consumption for the Data Center Market (Datacenter Automation Software and Hardware)	**4,700,000**	**0**
PG&E High Performance Office Lighting Systems Third-Party Program	**40,500,000**	**0**
Kitchen Demand Controlled Ventilation Third-Party Program (http://greenventkitchen.com/index.php).	**28,600,000**	**1,700,000**
EnerNOC/PG&E Monitoring-Based Commissioning Third-Party Program (http://www.enernoc.com/solutions/energy-efficiency.php)[2]	21,500,000	180,000
EnerNOC/Southern California Edison (SCE) Monitoring-Based Commissioning Third-Party Program[3]	**24,000,000**	**0**
UC/CSU/IOU Energy Efficiency Partnership Monitoring-Based Commissioning (MBCx) Program (savings achieved by 2004–2005, 2006–2008, and 2009 program cycles, http://www.uccsuiouee.org)	**31,000,000**	**2,800,000**
Additional monitoring-based commissioning (MBCx) project potential identified in UC Strategic Energy Plan project portfolios.	**33,000,000**	**3,000,000**

Notes:

1. These mainstream implementation programs were initiated primarily as a result of PIER SPEED Program activities and are focused on PIER technology. However, these programs do not use PIER technology exclusively. This means that savings figures are not directly comparable to those in Tables 2 and 3. Unless noted as "achieved," savings are as targeted at the time of this writing.
2. (See Layerle 2010)
3. (See Hand 2010)

4.5 Cost Sharing

4.5.1 Host Cost Sharing of Demonstration Projects

The Program began by fully funding demonstration projects. The initial emphasis on lighting technologies with relatively low equipment and installation costs made this possible. There was increased initiative to obtain cost sharing as the Program branched out to include several more market sectors and HVAC technologies, increasing demonstration costs. Host sites shared project costs for most of the projects in the last three years of the program, covering about one-third of total demonstration costs.

4.5.2 U.S. Department of Energy Cofunding of Field Research at UC Merced

In 2008 at the request of the Energy Commission, the program allocated funding for field R&D on three technologies, using the UC Merced campus as a test bed. These projects were heavily leveraged with co-funding from the U.S. Department of Energy, as well as in-kind effort from the United Technologies Research Corporation. The three technologies were chiller plant optimization, building performance visualization, and occupancy sensing for HVAC control utilizing low-resolution video technology. Please see Chapter 4, Sections 4.2.2 and 4.2.3, and Attachment III—Technical Reports for more information.

CHAPTER 5: Education and Training

5.1 Outreach Summary

The outreach and education components of the PIER Demonstrations program are critical features in the process of bringing products from the lab to the marketplace. Products that begin in PIER research and development projects are supported by a demonstration phase that proves the technology; the collected information is then offered to the larger energy-efficiency community through education and training efforts, which benefits the greater good and helps to seed the marketplace.

In a typical workflow, products developed in a project's research and development phase are left to fend for themselves in a competitive market environment, relying only on the marketing efforts of the adoptive manufacturer. In the PIER process, the products are tested in real-world scenarios and monitored over time to validate performance and gain implementation knowledge. This information is then disseminated through various outreach efforts to key audiences that value the more objective PIER program evaluation, rather than relying solely on manufacturer literature. These audiences include the facility managers that receive the PIER test products and the larger facility management community. Additionally, the PIER Demonstrations program outreach team engages the greater industry community to form strategic partnerships for the development of additional RD&D projects.

Typical venues for PIER Demonstration outreach efforts include a family of websites, the inclusion of speakers and displays at key industry conferences, papers or articles for industry publications, case studies, tours of the CLTC and WCEC facilities, photographic documentation of installation sites, signage for installation sites, and the production of supporting collateral events both hosted and attended by PIER Demonstration team members.

5.2 UC/CSU/IOU Energy Efficiency Partnership

The SPEED Program funded technical assistance to the training and education element of the 2004–2005 UC/CSU/IOU Energy Efficiency Partnership, with some follow-on activities in 2006. The New Buildings Institute provided information about PIER technologies to the developers of curriculum for new construction seminar and workshop offerings by the Partnership. The course offerings were targeted primarily at university capital project management personnel. Architect and engineering consultants working on university capital projects and university facility management personnel were also among the course attendees.

The Partnership offered 17 courses with a total of 65 sessions and over 600 training days for an estimated 400 individuals from 2004–2006. Content from 16 different PIER projects was a part of 8 of the courses and 27 sessions. More details can be found in the report *PIER UC/CSU Energy Efficient Campuses Program—Summary Report on PIER Research Integration into Training and Education for Higher Education Campus Staff through the UC/CSU/IOU Partnership* (see Attachment

VII—Training and Education Materials). Course materials that were augmented with information derived from PIER programs can also be found in Attachment VII.

5.3 Conferences and Forums

The Program initiated, co-developed, or provided major contributions to forums and conferences showcasing new technology for higher education facilities, including Campus Lighting Retrofit Forums at UC Davis and UC Irvine in 2009, special forums introducing Community College personnel to kitchen demand control ventilation technology in 2008, and the annual California Higher Education Sustainability Conference. Program staff regularly participate in other major technology transfer venues such as the Greenbuild conference, the ACEEE Summer Study, and the Utility Energy Forum. Key presentations can be found in Attachment VIII—Other Technology Transfer Materials.

5.3.1 California Higher Education Sustainability Conference

The Program participates in the Higher Education Sustainability Conference each year, through numerous on-campus lighting technology demonstrations, tours of the demonstrations, an exhibit booth, and by leading sessions.

5.3.2 Forums

The Program co-developed the Campus Lighting Retrofit Forums at UC Davis and UC Irvine in July 2009. Topics included: campus sustainability planning; funding for lighting retrofits; case studies given by campus managers; LED induction, and HID opportunities; exterior lighting technology options; office and classroom systems; and emerging technologies for lighting controls.

In 2008, the program organized two forums for California Community College campus decision-makers covering the Kitchen Demand-Controlled Ventilation technology demonstration activity. One was held at the PG&E Food Service Technology Center in San Ramon, California, and the other was held at the Southern California Gas Company Customer Center in Downey, California. Despite initial interest, no additional demonstration projects resulted from this outreach.

The Program staff presented at the 2008 and 2009 Utility Energy Forums.

5.3.3 Greenbuild

A team including the Energy Commission, CIEE, CLTC, and WCEC presented PIER Building End-Use Efficiency R&D with a focus on the SPEED Program at the 2008 and 2009 Greenbuild Conferences. (See Attachment VIII.)

5.3.4 ACEEE Summer Study

The California Energy Commission and CIEE jointly submitted a paper describing the SPEED Program for publication in the 2006 and 2008 Proceedings of the American Council for an Energy Efficient Economy (ACEEE) Summer Study on Energy Efficiency in Buildings (see Attachment VIII). The Program team presented the accepted papers and hosted additional informal sessions on PIER Demonstration opportunities at both the August 2006 and August 2008 conferences. The papers describe the unique model for technology transfer and market

transformation developed by the program. Partly as a result of this information dissemination, the New York State Research and Development Authority expressed interest in this type of program for New York. This led to conference calls in May 2010 to provide more information to approximately ten NYSERDA staff members.

5.4 Tools and Materials

Outreach and educational tools and materials are designed to help increase the speed and penetration of innovative energy-efficiency products into the marketplace. All of the programs and services help increase market penetration for PIER technologies and enhance benefits for early adopters.

5.4.1 PIER Lighting Technology Catalogs

PIER-sponsored RD&D has focused on developing integrated lighting systems for spaces such as classrooms, conference rooms, parking lots, and garages. These systems combine energy-efficient luminaires, multi-level control, occupancy sensors, and daylight harvesting. The cutting-edge lighting systems achieve 30 to 75 percent energy savings when compared to traditional lighting sources.

The energy-efficient luminaires are presented in two CLTC catalogs: PIER Solutions for Classrooms and Conference Rooms, and PIER Solutions for Parking Lots and Garages. The catalogs are used at trade shows and other special lighting events, and are available for download from CLTC's website. (See also "Websites" below.)

Printed catalogs are given only to select individuals, as they cost about $20 per copy to print. However, they have proved to a be a valuable tool to include at trade shows and conferences because they show the amount and variety of products that can be used to help achieve PIER's energy-reduction goals. Three versions of the PIER Solutions for Parking Lots and Garages and one version of the PIER Solutions for Classrooms and Conference Rooms have been released to date.

5.4.2 Virtual Mapping of Demonstrations

Terradex is a Web-based Geographical Information System (GIS) tool designed to help potential users of PIER technology locate demonstration sites in their geographic region and access relevant case studies and other technology information.[5] This site can be reached by links from CIEE's website (http://uc-ciee.org/). See also "Websites" below.

5.4.3 Videos (Virtual Tours)

The Program produced videos as virtual tours of demonstrations conducted at UC Davis, extending the impact of these leading-edge initiatives by the CLTC host campus.

5See PIER Partnership Demonstrations and Sustainability Monitoring, http://terradex.com/PublicPages/CIEE/PIER_01.aspx.

5.4.3.1 UC Davis Exterior Lighting Retrofit

This video highlights the UC Davis Exterior Lighting Retrofit, focusing on smart bi-level induction luminaires in the North Entry Parking Structure. The video can be downloaded from the CLTC website (www.cltc.ucdavis.edu) under "Demonstrations."

5.4.3.2 Wireless Integrated Photosensor and Motion Sensor (WIPAM)

This video features the wireless integrated photosensor and motion sensor system, focusing on Adura Technology's product and CLTC's role demonstrating it.

5.4.4 Websites

Websites allow SPEED to post program documents for access by target audiences from the various market sectors. For the 2004-2010 Program period, two primary websites contained substantial program content:

- State Partnership for Energy Efficient Demonstrations (SPEED)
- California Lighting Technology Center (CLTC)

5.4.4.1 SPEED

The SPEED website (www.pierpartnershipdemonstrations.com) is dedicated to the program and limited to content directly produced by the Program. Case studies, construction specifications, and other information can be accessed here. This site can also be reached by links from CIEE's website (http://uc-ciee.org/).

5.4.4.2 CLTC

The CLTC at UC Davis is one of the primary SPEED team members, conducting all lighting technology activities for the program. The CLTC maintains some SPEED Program content in the "Demonstrations" section of its website (www.cltc.ucdavis.edu), alongside other Center lighting demonstration activities. The CLTC communications group is able to track media references to the program, develop stories related to program activities, and otherwise post program information frequently.

In addition, the program is using a Geographical Information System (GIS) website to map demonstration activities across the state. (See "Virtual Mapping of Demonstrations" above.) This site can also be reached by links from CIEE's website page (http://uc-ciee.org/).

The Western Cooling Efficiency Center at UC Davis is another primary team member for SPEED. The WCEC is becoming increasingly active in conducting HVAC and other demonstrations for SPEED and will be posting demonstration project content on its website (www.wcec.ucdavis.edu).

5.4.5 Case Studies

Case studies help bridge the gap between the laboratory and the marketplace by informing commercial and residential end users of new energy-efficient technologies. The primary modes of distribution for the case studies is through the program website (www.pierpartnershipdemonstrations.com) and CLTC website (http://cltc.ucdavis.edu). The

case studies present an accessible, easily understood story about a select product or product category. To date, more than 20 PIER Demonstration Program case studies are available online.

In addition to Program-managed websites and the CLTC web site, PIER Demonstration vendor partners use the case studies to share success stories with interested buyers who are looking for a more objective opinion of new technologies. Partner manufacturers appreciate this valuable "third-party" perspective. Some of the manufacturers that use the case studies on a regular basis include Full Spectrum Solutions, Cooper Lighting, and Adura Technologies.

All Program case studies may be found in Attachment II:

Lighting case studies include:

- Bi-level LED Bollards
- Bi-level Street and Parking Area Luminaires
- Bi-level HID Wall Packs
- Bi-level LED Parking Garage Luminaires
- Bi-level Stairwell Fixtures
- Integrated Office Lighting System
- Energy-efficient LED Downlights
- Bi-level Induction Parking Garage Luminaires
- Wireless Integrated Photosensor and Motion Sensor
- Advanced CFL Downlights
- Hybrid Porch Light
- Hybrid Vanity and Wall Switch
- Integrated Classroom Lighting System
- Load Shed Ballasts
- Low-glare Wall Pack
- Open Digital Lighting Protocol

Heating, ventilation and air-conditioning case studies include:

- Demand Controlled Kitchen Ventilation
- Automated Fault Detection and Diagnostics
- Wireless Constant Volume to Variable Air Volume Conversion (Discharge Air Regulation Technique—DART)
- VAV Static Pressure Reset
- Large System Duct Sealing
- Data Center Automation Software and Hardware (DASH)

5.4.6 E Source Technical Briefs

Many technologies in the Program demonstration portfolio have been the subject of ESource Technical Briefs. Though these briefs were produced independently of the Program, the Program supplied substantial content. ESource PIER Technical Briefs are available to the public at: www.esource.com/public/products/cec_form_send.asp.

CHAPTER 6:
Market Transformation and Program Results

6.1 Manufacturers

The successful demonstration of new technologies gives product manufacturers positive feedback. This can either lead to more vendors offering the technology, or to new product lines using field-proven technology components. The Program has resulted in both of these types of derivative product development.

6.1.1 New Manufactures of Demonstrated Products

6.1.1.1 Kitchen Demand Controlled Ventilation Systems

Melink originally introduced its kitchen demand-control ventilation system in 2004. Demonstration by the Pacific Gas and Electric Company Emerging Technologies Program and State Partnership for Energy Efficient Demonstrations has led to market interest in this technology. This market pull has resulted in two other major companies offering versions of the technology. Whereas the Melink system was developed for retrofits, these other systems target new construction. The alternative systems do not have all the functionality of the Melink system, but may be beneficial in certain situations. It is expected that even more manufactures will produce retrofit solutions within the next few years as the market grows.

6.1.1.2 Bilevel Stairwell Luminaires

The PIER Program and NYSERDA originally developed the bi-level stairwell fixture with Lamar Lighting (Occusmart VO Series Luminaire). The success of the demonstrations and market entrance of this product line prompted several manufacturers to produce similar products. At least three of the alternative products meet the critical performance specifications of the original product and are considered acceptable "or equal" products: Cooper Lighting's Sure Lights®, Columbia Lighting's Bi-Level Luminaire, and the Ecovations Stairwell Luminaire. More recent demonstration products (for example, demonstration in-progress at Los Angeles Trade-Technical College) sometimes use the alternative products.

6.1.1.3 Classroom Lighting Systems

The PIER Program originally developed the integrated classroom lighting system with Finelite. As with bi-level stairwell lighting, the success of the demonstrations and market entrance of the product line led other manufacturers to produce similar products. At least three of the alternative products meet the critical performance specifications of the original product and are considered acceptable "or equal" products: Peerless Lighting (Classroom Lighting System), Litecontrol (CS/av), Cooper Lighting (Corelight- Smart Environments), and Alera Lighting (A+ Class). In addition, the Lithonia Lighting Classpack is a competing troffer retrofit lighting system with controls. More recent demonstration products (for example, demonstration in-progress at Los Angeles Trade-Technical College) sometimes use the competing products.

6.1.2 New Product Lines

The bi-level stairwell fixture succeeded in reducing energy use while maintaining a critical safety function in an application historically having high levels of lighting and energy use twenty-four hours a day, seven days a week. This success led to the investigation of the same approach to the similar application of parking garage lighting, as well as to street and parking lot lighting. This resulted in manufacturer development of bi-level garage, parking lot, and street lighting systems. This theme is now being repeated for corridor lighting

6.1.2.1 Bilevel Garage Luminaires

The PIER Program worked with manufacturers to apply the lessons learned from bi-level stairwell lighting to the development of bi-level parking garage fixtures using a variety of light sources: fluorescent, induction, and LED.

6.2 Codes and Standards

Research, development, and demonstration activities can also facilitate improved energy efficiency through support for Code and Standard development. The California Title 24 Building Energy Efficient Standard process is a major client for PIER, and the Program has contributed to advances in the lighting sections of the Standard. Program results can also inform appliance standards (for example, California Title 20), HVAC Standards (for example, ASHRAE 90.1), and climate protection regulation (for example, State Assembly Bill 32).

In addition, Program demonstrations have led some leading-edge partner organizations to introduce internal new construction and retrofit standards based on proven new technology.

6.2.1 Energy Code and Regulations

During the course of this program, some state and federal codes and standards underwent revisions that were stimulated by PIER lighting technologies and design practices. New regulations, most particularly at the state level, include specifications and technologies from the PIER lighting portfolio, and provide exceptions from certain requirements based on demonstrated PIER technologies. Program partners also continue to support energy efficiency standards and legislation efforts at all levels of government. For example, this support has influenced State Assembly Bill 32 (The Global Warming Solutions Act) and pending federal legislation (the American Clean Energy and Security Act of 2009). The following information represents a sample of these measures influenced by PIER research and development.

6.2.1.1 California Title 24 Code of Regulations Building Energy Efficiency Standards for Residential and Nonresidential Buildings

Title 24 2008, effective January 1, 2010, implemented several changes to the requirements for residential and non-residential spaces, influenced by PIER lighting technologies.

Section 119 Mandatory Requirements for Lighting Control Devices, Ballasts and Luminaires, Part (f) Automatic Daylighting Control Devices requires automatic daylighting control devices be auto commissioning or capable of remote commissioning. This requirement removes the potential for error during sensor commissioning caused from interference by the commissioning agent. The LS-102 photosensor offered by WattStopper utilizes the simplified daylight-harvesting

algorithm developed under the PIER Program. This sensor was the first automatic commissioning photosensor, and may be the only offering which meets the Title 24 auto-commissioning requirement. Other compliant photosensors come with hand-held devices that allow for remote commissioning, but it is expected, due to this code requirement, that more products will emerge with auto commissioning capabilities.

Section 119 Mandatory Requirements for Lighting Control Devices, Ballasts and Luminaires, Part (e) Multi-level Occupant Sensors is a new section of the Title 24 code, which describes the requirements for multi-level occupancy sensors. These sensors, also known as dual relay occupancy sensors, have been demonstrated as part of the Program, and have also been used in PIER-sponsored research to study the energy savings potential of various switching schemes in commercial office environments.

Based in part on the success of this work, the new provision was added to explicitly describe the necessary requirements of these devices. In addition, *Section 146 – Prescriptive Requirements for Indoor Lighting*, which mandates the total allowable power density for nonresidential spaces, requires that when these devices are used to qualify for power adjustment factors (credits against the total allowable power density), they must be configured such that the first light level only activates between 30 and 70 percent of the lighting power load (manual or automatic). This switching scenario, as demonstrated through PIER research and development, is shown to deliver the largest energy savings. Within residential spaces, Program partners were also helpful with regards to development of broad high-efficacy requirements for permanently installed luminaires, which includes exceptions for lighting controlled by these same types of occupancy sensors.

The next revision to Title 24 energy regulations, scheduled to begin in 2011, is expected to contain several provisions stemming from PIER lighting technologies and demonstrated practices. It is expected that regulations will contain some requirements for automatic multi-level control of certain types of exterior lighting such as the bi-level LED, HID, and induction exterior luminaires demonstrated in the Program. In addition, occupancy-controlled stairwell lighting may become mandatory. Bi-level, occupancy-controlled stairwell luminaires have been demonstrated extensively as part of the Program and manufacturers continue to bring new versions of these luminaires to market. There is even some discussion on mandatory requirements for multi-level or dimming ballasts for all new commercial office construction. This validity of this energy savings provision is supported by the Program demonstrations of the IOLS and Digital Addressable lighting controls technologies, which have been completed over the past four years. Program partners continue to be helpful and inform Title 24 stakeholders

6.2.1.2 California Title 20 Code of Regulations – Article 4. Appliance Efficiency Regulations

Program partners informed the requirements for *Section 1605.1 – Part N (1) Energy Efficiency Standards and Energy Design Standards for Torchieres*. This work stemmed from early development and demonstration work conducted by the Program, including some original torchiere development work conducted at Lawrence Berkeley National Laboratory. Recently,

the Berkeley Lamp II, a compliant, fully dimmable CFL torchiere, has been demonstrated as part of some Program Integrated Office Lighting System installations.

6.2.1.3 ASHRAE 90.1-2007 Energy Standard for Buildings Except Low-Rise Residential

In 2010, Program partners began working with the ASHRAE 90.1 lighting subcommittee on potential requirements for multi-level exterior lighting for parking lots and parking garages. The subcommittee recently approved a requirement for parking garage lighting controls, which will be recommended for inclusion in the next revision to the standard. The controls requirement states that parking garage luminaires must be controlled by one or more devices that automatically reduce the luminaire power by a minimum of 30 percent when no activity is detected within the lighting zone. This recommendation is derived directly from the bi-level garage luminaires first developed and demonstrated by PIER. Program support is ongoing to assist the subcommittee with recommendations for similar controls for area luminaires used in non-residential parking lots.

6.2.1.4 Heating, Ventilation, and Air Conditioning

Current Program demonstration experience can inform future updates of Title 24 Part 6 Building Energy Efficiency Standards, including sections 112.

The minimum efficiency requirements for electrically operated unitary air conditioners (Table 112 A) increased with the 2008 Title 24 update. The PIER technology demonstrations of very high efficiency air conditioning equipment, such as Western Cooling Challenge-certified units, can inform the next updates.

Section 112 C outlines new requirements for programmable thermostats that have setback capabilities. Proposed code language would have required significant communication capabilities to allow for, among other attributes, interface with demand response communications, but final revisions only added requirements for thermostats with setback controls. Program demonstrations include installations and evaluations of permanently installed diagnostic systems and controllers for unitary air conditioners with integrated capabilities for thermostat scheduling. Information from the demonstrations will provide valuable insight into the status practicality of emerging technologies in this field, and can inform the direction of the proposed code changes.

6.2.2 Lighting Standards and Specifications

Following successful PIER lighting demonstrations, several host sites implemented lighting standards or standards revisions to permanently incorporate demonstrated technologies in future retrofit and new construction projects. The following list of partners have updated or revised their lighting specifications and standards to include demonstrated PIER technologies. For more information on changes to these campus standards, please contact each host site directly.

- San Francisco State University: Integrated Classroom Lighting System (ICLS)
- Department of General Services: Bi-level induction garage lighting
- Los Angeles School District: Integrated Classroom Lighting System (ICLS)

- Citrus Community College: Integrated Classroom Lighting System (ICLS)
- California. Department of Motor Vehicles: Integrated Office Lighting System (IOLS)
- University of California, Davis: Smart bi-level exterior lighting
- University of California, Irvine (UCI): Smart bi-level exterior lighting

6.3 Utility Adoption: Partnerships and Programs

The Program engaged with a variety of utility energy efficiency programs including investor-owned utility partnerships with higher education institutions, Emerging Technology programs, and general incentive and rebate programs, as well as utility-administered third-party programs.

6.3.1 Investor-Owned Utility Partnerships

The Program has been coordinated with the UC/CSU/IOU Energy Efficiency Partnership since the inception of both in 2004. The CCC/IOU Energy Efficiency Partnership was also linked to the coordination of program demonstrations on community college campuses. See Chapters 3.1 and 5.1 for more information.

6.3.2 Utility Emerging Technology Demonstrations

The lighting demonstration activities completed under this Program fed directly into California utility Emerging Technology (ET) programs. The ET programs seek to evaluate emerging lighting products and practices, develop energy savings profiles, and fully vet the technologies for possible inclusion in utility rebate and incentive programs.

Program demonstration and information dissemination activities have a wide audience, seeking to support market transformation and widespread adoption of PIER technologies. While Program demonstrations and information dissemination activities are usually sufficient to facilitate adoption by individual end-users or by leading-edge implementation programs such as the IOU Partnerships, the additional ET program vetting is necessary for inclusion of technology in standard utility incentive programs.

When possible, collaborative projects with ET programs are able to gain advanced consideration for valuable incentive programs, which accelerates market adoption. Another scenario for collaboration with ET programs occurs when the demonstration project is of a scale or technical scope that is beyond the capabilities or resources of the individual programs. Specific examples of these unique partnerships are described below.

6.3.2.1 IOLS: Ziggurat Building, Sacramento, California

The CLTC contributed to an experimental IOLS retrofit in an office space in the Ziggurat Building in Sacramento, California, working jointly with Heschong Mahone Group (HMG), PG&E, and the California Department of General Services (DGS). The IOLS was developed at CLTC through funding from the PIER Program.

The goal of this IOLS project was to successfully implement at 25 workstations an innovative combination of five lighting-design tools—high-quality task lighting, cost-effective ambient

lighting reduction, zonal occupancy controls, daylight harvesting integration, and demand response technology—and ultimately retrofit the entire building.

6.3.2.2 Bilevel LED Street Lighting: San Jose, California

An estimated 60 million street and area lights currently are in operation in the United States, and this number is expected to continue growing over the next decades. Concerns regarding energy efficiency and light pollution are growing as well.

To address these problems, the PIER Program funded the development and demonstration of occupancy-based lighting controls and broad-spectrum light sources to create intelligent, bi-level luminaires designed for street and parking area applications.

Energy Solutions provided monitoring, data collection, and data analysis services for this LED Street Lighting and Network Controls Assessment Project under contract to PG&E's Emerging Technologies Program. The project was conducted in collaboration with the City of San Jose and the CLTC. This project replaced 55 watt nominal low-pressure sodium (LPS) streetlights with dimmable networked LED luminaires (75 watt nominal at full power) in the demonstration area. This project also included functionality testing and energy performance assessment of the streetlight network controls technology.

6.3.2.3 Bilevel Induction Parking: University of California, San Francisco (UCSF)

The CLTC partnered with UCSF and the PG&E Emerging Technologies program to replace 150-watt HPS shoebox fixtures and 400 watt HPS cobra heads with 100 watt bi-level induction shoebox and cobra head fixtures manufactured by Everlast Lighting. This retrofit was similar to the California Department of Public Health (CDPH) Richmond facility retrofit, except that the scale and the diversity of fixtures was larger at UCSF, where varying pole heights, wattages, and fixture types were retrofitted with a single wattage of cobra head and shoebox fixtures.

The quantification of actual energy and cost savings was determined in a similar fashion as the CDPH retrofit. Details can be found in Attachment III—Technical Reports, Lighting Demonstration Site Reports.

6.3.2.4 University of California Santa Barbara Recreation Center Zero Net Energy Retrofit

The Program is partnering with Southern California Edison for the zero-net energy (ZNE) retrofit of the UC Santa Barbara Recreation Center. A design charrette was held in 2009 in parallel with initial Program demonstrations in conjunction with the 2009 California Higher Education Sustainability Conference. Ongoing meetings in 2010 have led to a commitment to continue the design process and finalize the ZNE retrofit design by the end of 2010, for implementation in 2011. More details can be found in Attachment III—Technical Reports

6.3.3 Incentive and Rebate Programs

In commercial buildings, electric lighting may be responsible for over 30 percent of the total electrical load. A wide range of lighting technologies have been developed through the PIER program and are listed in public utilities catalogs with applicable incentives that include rebate opportunities to encourage businesses to reduce this demand. Through these programs, businesses are encouraged to install energy-efficient lighting technologies. These installations

must be new or retrofit and replace a previously installed product. All available products are offered in catalogs, which are developed and made available through each public utility. The following is a listing of general lighting technologies that qualify for utility rebates and incentives, categorized by the public utility that developed the incentive. Many PIER technologies fall into these categories.

6.3.3.1 Pacific Gas and Electric

- Exterior Induction Fixtures
- Exterior HID Fixtures w/Electronic Ballasts
- Bi-Level Stairwell/Hall/Garage Fixtures
- ENERGY STAR Light Emitting Diode (LED) Surface, Pendant, and Recessed Downlight Fixtures
- Occupancy Sensors
- Exterior Photocells

6.3.3.2 SMUD

- Interior and Exterior Lighting Retrofits (excluding screw-in compact fluorescent lamps)
- Lighting Control Systems
- Daylighting Systems and Dimmable Ballast
- Ceiling- or Wall-mounted Lighting Sensor
- Occupancy Sensor - Wall-box
- Bi-Level Stairwell/Hall/Garage Fixtures

6.3.3.3 San Diego Gas & Electric

- Exterior Induction Fixtures
- Interior LED Fixtures
- Exterior LED Fixtures
- Bi-Level Stairwell/Hall/Garage Fixtures
- Wall- or Ceiling-Mounted Lighting Sensor
- Fixture Integrated Occupancy Sensors
- Exterior Photocell

6.3.3.4 Southern California Edison

- Occupancy Sensors and Photocells
- Exterior and Interior Fixtures
- Table Lamps, Desk Lamps, Floor Lamps, and Torchieres
- Night Lights (including LED)
- Interior LEDs (non-night lights)

- Lighting Controls
- Exterior HID

6.3.4 Third-Party Programs

Utility-administered third-party programs have sometimes specifically targeted Program-supported technologies such as Demand Controlled Kitchen Ventilation and Monitoring-Based Commissioning. Other third-party programs target a market sector with Program demonstrated solutions such as office lighting. The achieved savings or savings targets for these programs are included in Section 4.4.1, Table 4—Achieved or Targeted Savings of Deployment Programs Using PIER Technologies Demonstrated by the State Partnership for Energy Efficient Demonstrations (SPEED) Program.

6.3.4.1 PG&E High Performance Office Lighting Systems Third-Party Program

The High Performance Office Lighting program targets lighting retrofits and designs for offices, warehouses and other large commercial buildings. The focus is on task/ambient design, integrating overhead lights, task lights, and controls for large energy-efficiency and demand-response savings. Amtech and other lighting partners will deliver the program. Many of the IOLS, ICLS, bi-level lighting, daylight controls, and other PIER-developed solutions will be used in this program. The overall budget is $10.7 million, and the targeted savings is 40.5 million kWh per year.

6.3.4.2 PG&E GreenVent for Kitchens (Demand Controlled Kitchen Ventilation) Third-Party Program

The GreenVent for Energy Efficient Kitchens program is a turnkey program to deliver substantial energy savings by offering incentives for the installation of demand ventilation control in commercial food service facilities. The program budget is $9.1 million, with expected savings of 28.6 million kWh and 1,700,000 therms per year. See http://greenventkitchen.com/restaurant.php for more details.

6.3.4.3 Monitoring-Based Commissioning Third-Party Programs

The UC/CSU/IOU Partnership successfully piloted monitoring-based commissioning (MBCx) as a major program element for the 2004–2005 and 2006–2008 energy efficiency funding cycles. The UC/CSU/IOU Partnership continued this program element for the 2009 and 2010–2012 funding cycles, and the California Community College/IOU Partnership also began funding MBCx projects with the 2006–2008 cycle.

Commissioning consultants working on UC/CSU/IOU Partnership projects in 2004–2008 proposed third-party monitoring-based commissioning programs for the 2009–2011 energy efficiency program cycle in the PG&E and SCE service territories. Details can be found in Section 4.4.1, Table 4.

6.4 State Energy Program/American Recovery and Reinvestment Act Programs

Public Interest Energy Research technology figured prominently in energy-efficiency programs awarded funding by the American Recovery and Reinvestment Act (ARRA) State Energy Program. The SPEED Program helped bring the technologies to the point where they could be a core part of this economic stimulus initiative in California. For a tabulation of savings targets for these programs, please see Section 4.4.1.

6.4.1 Municipal and Commercial Building Targeted Measure Retrofit Program

The California Energy Commission solicited proposals in 2009 for the Municipal and Commercial Building Targeted Measure Retrofit Program, funded by the ARRA State Energy Program. This solicitation targeted deployment of PIER technologies demonstrated by the SPEED Program. Two of the three projects that received awards in March 2010 included substantial use of demonstrated technologies.

The CLTC is a proposed team member for the number one-ranked proposal by Energy Solutions, whose award of $5,949,739 for its Energy Technology Assistance Program will serve municipalities in the Greater Bay Area, Southern California, and Sacramento.

Quantum Energy Services & Technologies will also use PIER technologies proven through the SPEED Program for the Downtown Oakland Targeted Measure Saturation Project, funded with an award of $4,852,181.

The PIER lighting technologies included in the Municipal and Commercial Building Targeted Retrofit Program are:

- Advanced CFL Downlights
- Simplified Daylighting Controls
- Wireless Lighting Controls
- SMART Wall Pack Fixtures
- SMART Parking Lot and Parking Garage Fixtures
- Integrated Office Lighting System
- Integrated Classroom Lighting System

The PIER HVAC technology included is:

- Wireless HVAC Controls

6.4.2 Active Management of Cooling Systems to Reduce Energy Consumption for the Data Center Market (Datacenter Automation Software and Hardware)

Federspiel Controls gained experienced in deploying its Datacenter Automation Software and Hardware technology through participation in the State Program for Energy Efficient Demonstrations. The demonstration of the technology at the California Franchise Tax Board facility in Sacramento led to a successful proposal for $584,078 of ARRA State Energy Program funds for retrofit of the technology in ten State of California datacenters.

6.5 California Public Utility Commission (CPUC) Interactions

Many PIER technologies were selected for use in the newly developed CPUC 2010–2012 Statewide Lighting Market Transformation (LMT) program. These technologies exemplify best lighting practices and provide deep energy savings—typically 50 percent more than standard practices. The CPUC Strategic Lighting Plan in progress is based on a goal of shifting California from standard practices to best practices (CPUC 2010a). The 2010 Lighting Technology Overview produced for the CPUC uses the same PIER technologies as cited in the new 2010–2012 Statewide IOU LMT plan as examples of the 10-year results from supporting best practices versus standard practice (CPUC 2010b). To achieve the CPUC's 2020 lighting goals, it will be necessary to continue the development of the PIER lighting technologies and best practices.

6.6 Awards

6.6.1 Lightfair® International (LFI) Innovation Awards

Program technologies have won Lightfair ® International Innovation Awards.

6.6.1.1 2010 LFI

The CLTC affiliate Deco Lighting won an LFI Innovation Award for the best fluorescent-based troffers, suspended, and surface luminaires for its DecoSMART bi-level (DSBL) stairwell luminaire with DecoSMART system. For more information, see: http://cltc.ucdavis.edu/content/view/749/.

6.6.1.2 2008 LFI

Two California Energy Commission/PIER products won awards in 2008: SPOT won the International LightFair 2008 Most Innovative Product of the Year award and the Sylvania Power Shed high-efficiency demand response ballast also won an innovation award.

6.6.2 Design Journal's 2009 ADEX Award

Design Journal presented the 2009 Award for Design Excellence (ADEX) to Full Spectrum Solutions, Inc. for the Berkeley Lamp II. The ADEX Award is "the largest and most prestigious awards program for product design of furniture, fixtures and finishes marketed to the design trade." Sponsored by *Design Journal,* the international trade publication for interior designers, architects, and facility managers, ADEX Award recipients are recognized for superior product design. Receiving a 2009 ADEX Award among 2,000 other innovative product nominations, the patented Berkeley Lamp II proved to impress the judges. Chosen by an anonymous panel of professionals, the ADEX Award represents the best product designs of the year in the opinion of those who reside at the top of their specialty, in this case, the lighting design experts.

Developed by Full Spectrum Solutions in partnership with the CLTC, and with support from local California utilities and funding from the PIER program and U.S. Department of Energy, the Berkeley Lamp II improved on its original design with increased optics, performance, and reliability. For more information, see: http://cltc.ucdavis.edu/images/_news/press_releases/2009/2009_07_berkeley_lamp_wins_adex_award.pdf.

6.6.3 UC and CSU Best Practice Awards

The University of California and California State University systems make Best Practice Awards in a number of energy-efficiency categories as a part of the Sustainability in Higher Education Conference and in conjunction with the UC/CSU/IOU Partnership. The PIER SPEED Program projects have won a number of these awards.

6.6.3.1 2009 UC Best Practice Award

EverLast® Smart Light Garage fixtures helped UC Davis win a 2009 UC Best Practice Award by incorporating step-dimming controls in retrofits for increased pedestrian safety and unmatched energy savings. For more information, see http://cltc.ucdavis.edu/content/blogcategory/59/296/.

6.6.3.2 2009 CSU Best Practice Award

Cal Poly San Luis Obispo won a 2009 CSU Best Practice Award for their building retrofits using a number of Program Technologies including smart bi-level exterior lighting, LED bollards, LED area lighting, induction parking lighting, bi-level stairwell lighting, kitchen demand control ventilation, and discharge air regulation technique (DART) HVAC controls.

Sonoma State won a 2008 CSU Best Practice Award for the remodeling of Darwin Hall in a design-build process using Program technologies including the ICLS, bi-level stairwell fixtures, and advanced CFL downlights.

6.6.3.3 2008 CSU Best Practice Award

UC Berkeley won a 2008 UC Best Practice Award for a retrofit using the Program supported Adura wireless lighting controls. The University of California, Berkeley, saves $14,000 annually using the technology in two libraries—allowing staff to set operation schedules for fixtures that previously could not be turned off. The product requires no rewiring, making it convenient for in-house staff to implement in a variety of spaces.

6.6.3.4 2007 UC Best Practice Award

The UC Davis Housing unit won a 2007 UC Best Practice award for retrofitting residential bathrooms with a PIER-developed smart bathroom fixture. The technology integrates a motion sensor with an LED night light, turning the main lights off when unoccupied.

The University of California, Berkeley, won a 2007 Best Practice Award for using the PIER-developed DART system by Federspiel Controls to improve the operation of variable air volume (VAV) HVAC systems.

6.6.4 U.S. Department of Energy-Sponsored Lighting For Tomorrow Awards

The Program supported LED task lighting by Finelite won 2007 Lighting for Tomorrow awards for the under cabinet and desk/task lights, as well as for the system, which uses an occupancy sensor to turn the lights off.

This Finelite LED task lighting system has won several other industry awards since 2007.

6.6.5 Flex Your Power Awards

Program technologies have been honored with a Flex Your Power award and an honorable mention.

6.6.5.1 Fourth Annual Flex Your Power Awards—Innovative Products and Services ·Honorable Mention 2006)

The CLTC was the recipient of a Flex Your Power Innovative Products and Services Honorable Mention in 2006 for its California Kitchen Lighting System featuring advanced CFL downlights. For more information, see http://www.fypower.org/news/?p=653.

6.6.5.2 Fifth Annual Flex Your Power Awards—Innovative Products and Services (2007)

Finelite, Inc. was the recipient of a Flex Your Power Innovative Products and Services award in 2007 for its LED-based personal lighting systems, demonstrated by the Program as the Integrated Office Lighting System. For more information, see http://www.fypower.org/news/?p=1713.

6.7 Integrated Classroom Lighting System Specification Adoption

After the initial ICLS specifications were developed, SCE, working with the Los Angeles Unified School District (LAUSD), co-funded an ICLS demonstration in their classroom demonstration space that incorporated daylighting and developed additional daylighting features into the ICLS specifications. The revised ICLS specifications were adopted by LAUSD and the Collaborative for High Performance Schools.

Other organizations are considering adopting the specification, while San Francisco State, UC Berkeley, and Citrus Community College have installed multiple ICLS systems.

6.8 Group Purchasing

Group purchasing is a creative, cost-effective solution for incorporating demonstrated PIER technologies into new construction and retrofit projects.

Group purchasing eliminates several key barriers identified during recent technology demonstration projects, such as product coordination and cost constraints. By combining product orders from multiple campuses, participants meet order quantities that qualify for volume discount pricing. In addition, group purchasing can coordinate sole-source justification procedures, facilitating expeditious and cost-effective purchase of PIER technologies without the need for public bidding. This process eliminates excessive vendor markups and time delays.

The SPEED Program has successfully coordinated a group purchase of 1,275 bi-level stairwell fixtures for UC campuses in conjunction with the UC/CSU/IOU Energy Efficiency Partnership. The Program is exploring other group purchase projects, including one for exterior bi-level lighting.

CHAPTER 7: Conclusions and Next Steps

Public Interest Energy Research programs produce technologies and applications knowledge with the potential to significantly reduce energy end-use in the buildings and agriculture/ industry/water end-use sectors. A dedicated demonstration program can significantly accelerate the market adoption of these products. The State Partnership for Energy Efficient Demonstrations (SPEED) Program effectively employs University RD&D Centers and a variety of tools, including case studies, guide specifications, technology catalogs, virtual tour videos, training and education materials, and other technology transfer resources, to cross the "valley of death" that often stalls new technology. This variety of methods is necessary to maximize the dispersion of technology and applications knowledge in diverse market settings.

The Program has been highly successful in facilitating integration of new technology into utility energy efficiency and economic stimulus programs, as well as stimulating manufacturers to offer more new technology in their product lines. Ongoing program activities will continue to accelerate market adoption of new technology in similar fashion.

7.1 Demonstration Lessons Learned and Derivative Products/ Technologies

The real-world conditions encountered by a demonstration program provide the most stringent test of new technologies and application knowledge. While some technologies pass such vetting and can immediately have a substantial market impact, demonstrations often reveal weaknesses that prompt more research or product development. Demonstrations can also provide the feedback crucial to the creation of the next-generation "derivative" products. Demonstration activities can even foster the development of a new class of technology, as occurred with bi-level exterior lighting products derived from bi-level stairwell products.

7.2 Working in the Various Market Sectors

Higher education campuses provide a good setting for technology demonstration. The culture of learning and professional accomplishment often found among facility personnel leads to a desire to try new things and the opportunity to demonstrate newer technologies. Students and faculty add to the rich innovation environment, along with leadership present in systemwide management that minimizes the effort needed to organize demonstration activities.

Demonstrations in government organization facilities are necessary to foster technology adoption in this important sector. Increased outreach to local governments could be an effective direction for future phases of the Program. There is also interest in PIER technologies in the private sector, where demonstrations will play a major role in market acceptance. Increased outreach and coordination efforts will be necessary to develop a critical mass of demonstration activity in these sectors.

7.3 The Role of University Centers

The university RD&D center is an effective model for demonstration activities, with the right mix of faculty, student, and staff personnel to conduct and document demonstration projects. University RD&D centers can work with both university and private technology providers in demonstrating and evaluating technology.

7.4 Program Success

The Program has been highly successful in fostering new manufacturers to offer products and develop new product lines based on demonstrated technologies. The Program has also strongly supported the evolution of codes and standards tracking new technology, as well as compelling institutional organizations to adopt demonstrated technologies as internal standards. The Program has enabled integration of demonstrated technologies into utility energy efficiency and economic stimulus programs, as well as into the California Long Term Energy Efficiency Strategic Plan. Program activates have been recognized with multiple awards. The result has been accelerated market adoption of new energy efficiency technology.

7.5 Ongoing Activity

The Program continues to facilitate market adoption of new technology through ongoing demonstrations, special technology transfer projects, and market transformation activities in follow-on phases. Acceleration of technology adoption can continue in more market sectors and for more PIER products with continued demonstration and information dissemination efforts. Executive Order S-20-04 calls on all building sectors, including the private sector, to reduce energy usage. This compels Program activities across all building types, including all public education, government and private entities—to maximize the potential of PIER products and meet state energy-efficiency and climate-protection goals. The local government and private sectors present the greatest opportunity for expansion of Program efforts.

The Program is positioned to continue effective efforts to include PIER technology in market transformation. The historic level of funding for the Program will need to be maintained to maintain momentum toward the expansive and comprehensive statewide goals. Increased funding can be effectively used to achieve an even more rapid and widespread adoption of PIER technology and progress toward Program goals. Leveraging Program funding with resources from deployment programs and demonstration host sites will maximize program effectiveness. The Program process might be replicated for other California Energy Commission programs or in other states.

GLOSSARY

ACEEE	American Council for an Energy-Efficient Economy
ADEX	Award for Design Excellence
AEC	Architectural Energy Corporation
ARRA	American Recovery and Reinvestment Act
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
A/V	Audio/Visual
BAS	Building Automation System
CCC	California Community Colleges
CFL	Compact Fluorescent Lamp
CDPH	California Department of Public Health
CIEE	California Institute for Energy and Environment
C	Carryover Project
CLTC	California Lighting Technology Center
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent as greenhouse gas
CP	Capital Projects
CV	Constant Volume
CSU	California State University
DALI	Digital Addressable Lighting Interface
DART	Discharge Air Regulation Technique
DAS	Data Acquisition System
DASH	Datacenter Automation Hardware and Software
DGS	Department of General Services
DX	Direct Expansion
EB	Existing Buildings
EIS	Energy Information System
EISG	Energy Innovation Small Grant

EM	Energy Management
EMCS	Energy Management and Control System
ESCOs	Energy Service Companies
ET	Emerging Technology
FMS	Facility Management System
FSTC	Food Service Technology Center
FTB	Franchise Tax Board
GIS	Geographic Information System
HID	High-Intensity Discharge
HPS	High Pressure Sodium
HVAC	Heating Ventilation and Air-Conditioning
IAW	Industrial/Agriculture/Water
IAQ	Indoor Air Quality
ICLS	Integrated Classroom Lighting System
IMDS	Information, Monitoring, and Diagnostic System
IOLS	Integrated Office Lighting System
IOU	Investor-Owned Utility
IT	Information Technology
kWh	Kilowatt-hour
LATTC	Los Angeles Trade and Technical College
LAUSD	Los Angeles Unified School District
LBNL	Lawrence Berkeley National Laboratory
LD&A	Lighting Design and Applications
LED	Light emitting diode
LEED™	Leadership in Energy and Environmental Design
LMT	Lighting Market Transformation
LPS	Low Pressure Sodium
LRP	Lighting Research Program

MDL	Micro Data Logger
MWh	Megawatt-hour
MBCx	Monitoring-Based Commissioning
NBI	New Buildings Institute
NEMA	National Electrical Manufacturers Association
NYSERDA	New York Energy Research and Development Authority
N	Non-State (Auxiliary) Facilities
P	Capital Project
PG&E	Pacific Gas and Electric
PIER	Public Interest Energy Research
PMs	Project Managers
RD&D	Research, Development and Demonstration
SCE	Southern California Edison
SEP	State Energy Plan
SLO	San Luis Obispo
SMUD	Sacramento Municipal Utility District
SPEED	State Partnership for Energy Efficient Demonstrations
SPOT	Sensor Placement Optimization Tool
SVLG	Silicon Valley Leadership Group
T	Training and Education
TE	Taylor Engineering
T24	Title 24
T&E	Training and Education
UC	University of California
UCD	UC Davis
UCI	UC Irvine
UCSB	UC Santa Barbara
UCSF	UC San Francisco

U.S. DOE	United States Department of Energy
VAV	Variable Air Volume
WCEC	Western Cooling Efficiency Center
WIPAM	Wireless Integrated Photosensor and Motion Sensor System
ZNE	Zero Net Energy

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Appendix A: Attachments

I. Interim Reports

- I.1 *PIER Energy Efficient Campuses Demonstration Program: 2004–2007 Interim Report*
- I.2 2008 Technology Assessment – Initial Lighting Portfolio for Demonstration

II. Case Studies

- II.1. HVAC
  - II.1.1. Demand Controlled Kitchen Ventilation
  - II.1.2. Automated Fault Detection and Diagnostics (ENFORMA)
  - II.1.3. Wireless CV to VAV Conversion (DART)
  - II.1.4. VAV Static Pressure Reset
  - II.1.5. Large System Duct Sealing
- II.2. Interior Lighting
  - II.2.1. Integrated Office Lighting System
  - II.2.2. Integrated Classroom Lighting System
  - II.2.3. Downlights
  - II.2.4. Hybrid Vanity and Wall Switch
  - II.2.5. Load Shed Ballasts
  - II.2.6. Bi-level Stairwell Fixtures
- II.3. Exterior Lighting
  - II.3.1. Low Glare Wall Pack
  - II.3.2 Hybrid Porch Light
  - II.3.3. Bi-level LED Bollard
  - II.3.4. Bi-level HID Wallpack
  - II.3.5 Parking Garage Luminaires
    - Bi-level Induction at UCD
    - Bi-level Induction with WIPAM at UCSB
  - II.2.6. Bi-level Street and Area Lighting
- II.4 New Construction and Renovation Technology Applications
- II.5. Datacenter Technologies – IAW Area
  - II.5.1. Datacenter Automation Software and Hardware (DASH)

III. Technical Reports

- III.1. HVAC Technologies
  - III.1.1. Chiller Plant Optimization at UC Merced (LBNL)
  - III.1.2. Occupancy Sensing at UC Merced (LBNL)

III.1.3 VAV Design Guide Application Study (LBNL)
III.2. Lighting Technologies
III.2.1. Lighting Demonstration Site Reports (CLTC)
III.1.2. Open Digital Lighting Protocol (CLTC)
III.3. Energy Management Technologies
III.3.1 Monitoring-Based Commissioning – MBCx (LBNL)
Needs Assessment and Case Studies
MBCx Architectures
Automated Diagnostics for HVAC Control Loops: Oct 07
III.3.2. Benchmarking UC CSU IOU 2005 MBCx Portfolio (LBNL)
III.3.3. Energy Information Systems (LBNL)
III.3.4. Data Visualization at UC Merced
Energy Performance Visualization (LBNL)
Steam System Evaluation (Quest)
III.4. Data Center Technologies – IAW Area
III.4.1. DASH at FTB (LBNL, Federspiel Controls)
III.4.2. Temperature Sensors at Intel (LBNL, Federspiel Controls)
III.4.3. Liquid-Cooled Server at Sun (Clustered Systems)
III.5. Laboratory Technologies – IAW Area
III.5.1. Centralized Demand Controlled Ventilation (LBNL, UCI)
IV. PIER Technology Catalogs
IV.1. 2009 PIER Solutions for Classrooms and Conference Rooms
IV.2. 2010 PIER Solutions for Parking Lots and Garages
V. Derivative Product Descriptions – Cut Sheets
V.1. HVAC Technologies (no derivative products at this time)
V.2. Interior Lighting
V.2.1. Classroom Lighting Systems
V.2.2. Bi-level Stairwell Luminaires
V.3. Exterior Lighting
V.3.1. Bi-level Exterior Lighting
VI. Guide Specifications
VI.1. HVAC Technologies
VI.1.1. Discharge Air Regulation Technique (DART)
VI.1.2. Kitchen Demand Controlled Ventilation
VI.2. Interior Lighting
VI.2.1. Integrated Office Lighting System (IOLS)
VI.2.2. Integrated Classroom Lighting System (ICLS)
VI.2.3. Advanced CFL Downlight Package

VI.2.4. Hybrid Bathroom Vanity Luminaire Package

VI.2.5. Hybrid Bathroom Wall Switch Package

VI.2.6. Smart Bi-level Stairwell Package

VI.3 Exterior Lighting

VI.3.1. Smart Bi-level LED Bollard Package

VI.4 LEED® Guides

VI.4.1 LEED® for Commercial Interiors

VI.4.2 LEED® for New Construction

VII. Training and Education Materials

VII.1. Support for 2004-07 UC-CSU-IOU Partnership

VII.1.1. Summary Report (NBI)

VII.1.2. LEED for Project Managers Course Materials (Paladino)

VII.1.3. Exceeding T24 for Project Managers Course Materials (Eley)

VII.1.4. Building Controls for Project Managers Course Materials (TE)

VII.1.5. Lighting for PMS Course Materials (TMT)

VII.1.6. HVAC Design & Procurement Solutions Course Materials (TE)

VII.1.7. PIER Lighting Products for ESCOs Course Material (KJ)

VII.1.8. MBCx Course Materials (PECI)

VIII. Other Technology Transfer Materials

VIII.1. Briefing Materials

VIII.1.1. VAV Static Pressure Reset

VIII.1.2. Technology List Through 2008

VIII.2. Key Presentations

VIII.3. Technology Application Surveys

VIII.4. Published Papers

VIII.4.1. LD+A Article June 2008, DALI

VIII.4.2. 2008 ACEEE Summer Study (SPEED Model)

VIII.5. Conference Technology Showcase Tour Flyers