Public Interest Energy Research (PIER) Program

FINAL PROJECT REPORT

STATE PARTNERSHIP FOR ENERGY EFFICIENT DEMONSTRATIONS

2012–2014

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PREFACE

The California Energy Commission Public Interest Energy Research (PIER) Program 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 PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program 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.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

PIER Demonstration Program: State Partnership for Energy Efficient Demonstrations 2012–2014 is the final report for the State Partnership for Energy Efficient Demonstrations (originally UC/CSU Energy Efficient Campuses) project (contract number 500-10-049), conducted by the California Institute for Energy and Environment. The information from this project contributes to PIER's Buildings End-Use Efficiency Program.

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

ABSTRACT

From March 2012 through July 2014, the State Partnership for Energy Efficient Demonstrations (SPEED) accelerated the market adoption of energy-efficient technologies. This Public Interest Energy Research Buildings End-Use Efficiency Program supported effort included lighting and heating, ventilation, and air-conditioning (HVAC) technologies. Initiated in April 2004, this collaboration with industry, public entities, and utilities focuses on field research, beta testing, demonstrations, and activities facilitating technology deployed by California energy-efficiency programs. This report highlighted technologies and projects, and summarizes and indexes technical reports, case studies, guide specifications, and other documents created by the program.

The SPEED Program extended previous successes demonstrating newer technologies on University of California and California State University campuses. The program also extended its scope to developing business cases that facilitate adopting previously demonstrated technologies by the campuses. SPEED emphasized assistance with scaled deployment of PIER technology, concentrating on the projects with the University of California/California State University/Investor-Owned Utility Energy Efficiency Partnership—a public purpose-funded program administered by the California Public Utilities Commission to increase energy efficiency on California campuses. Previous SPEED Program efforts have also resulted in PIER technologies being included in California Public Utilities Commission/Investor-Owned Utility-administered third-party implementation programs, American Recovery and Reinvestment Act State Energy Program economic stimulus programs, and the 2013 update of the California Title 24 Building Energy Efficiency Standards.

The SPEED program-demonstrated technologies could eventually reduce annual California energy use by as much as 3.6 billion kilowatt-hours and 97 million therms in retrofit applications alone, eliminating annual carbon-dioxide equivalent (CO_{2e}) emissions by 1.5 million metric tons. Substantial progress has been documented toward this market potential, with achieved or targeted savings from scaled deployments of demonstrated PIER technologies now totaling 183 million kilowatt-hours per year and 7.1 million therms per year.

Keywords: California Energy Commission, Public Interest Energy Research, State Partnership for Energy Efficient Demonstrations, SPEED Program, emerging technologies, energy efficient, market transformation, lighting, HVAC, demonstration, valley of death, energy savings, building efficiency

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Introduction

New technologies must overcome numerous market barriers to be stable and successful. These barriers, or the "valley of death," can prevent technologies from achieving success. Funding and research must support technologies to face these barriers, which include lack of customer knowledge, issues with marketing and distribution channels, high initial mark-ups from designers and installers, and mistrust of savings and benefits. In 2004, the State Partnership for Energy Efficient Demonstrations (SPEED) Program was created by the California Energy Commission to accelerate market adoption of technologies developed or enhanced with the Public Interest Energy Research Program (PIER) funding. This program partnered with industry, public entities, and utilities to overcome the market barriers facing these innovative energy-efficient technologies, to help California reduce energy use, carbon dioxide (CO_2) emissions, and peak demand.

The SPEED program was designed to help companies develop products with energy efficient technologies cross the "valley of death" and gain a foothold in the marketplace. The program accomplishes this through demonstrations accompanied by a variety of technology transfer activities, including outreach to utility incentive programs and input to code change proposals—supported by case studies, fact sheets, guide specifications, and business cases. All of these efforts help emerging technologies gain market success, achieve anticipated energy and cost savings, and expand the impact of research, development, and demonstration investments. Persistent program efforts have now resulted in substantial energy reduction from scaled deployment of multiple technologies; accruing annual cost savings more than double the total investment in the program.

This program exemplifies the Public Interest Energy Research program goals of developing strategic public-private partnerships to build on successful research, development and demonstration projects and leverage investments throughout the state—delivering practical, quantifiable energy, environmental, and economic benefits to California and its citizens.

Purpose

From mid-2004 through early 2012, the Energy Commission's Buildings End-Use Energy Efficiency Research program and Industrial, Agriculture, and Water End-Use Energy Efficiency Research program areas provided $8.6 million to the SPEED program to demonstrate and field-test promising PIER technologies, conduct technology transfer activities, and support accelerated market adoption. The program was extended to mid-2014 with an additional $2.2 million of Buildings Efficiency funding.

As an administering institution for the program, the California Institute for Energy and Environment of the University of California led the planning, implementation, and documentation of the demonstration projects and other activities. In 2012–2014, additional primary team members included the California Lighting Technology Center, the Western

Cooling Efficiency Center at UC Davis, and the Center for the Built Environment at UC Berkeley.

The program is designed to catalyze introducing 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, to become "mainstream." Team members work with manufacturers in the research and development phase to evaluate and develop energy-saving products to meet energy and market needs. The program then conducts demonstrations in public facilities to validate the field performance of the most promising technologies. Partnership with University of California campuses and other demonstration hosts greatly increase the efficiency of the program, and those participants sometimes provide expert feedback for product improvements and derivative products. This collaboration leads to programs adopting and installing energy efficient technologies supporting state energy and sustainability goals. The program also links to electric utility programs and incentives, informs code changes in California's Title 20 Appliance Codes and Title 24 Building Energy Codes, stimulates market demand and supplier interest, and identifies customer needs for derivative products. As a whole, this process provides faster and more widespread market adoption of supported technologies.

Process

The first three years of the program (2004–2007) focused on developing partnerships with the University of California and the California State University campuses to demonstrate more than a dozen new PIER technologies. There was also emphasis on building the capabilities of the California Lighting Technology Center at UC Davis and partnering with the UC/CSU/Investor-Owned Utility Energy Efficiency Partnership to help campuses meet their energy efficiency goals. In its second three years (2007–2010), the program began working with the Western Cooling Efficiency Center at UC Davis, expanded its scope to encompass University of California and California State University auxiliary groups, 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 the program shifted to a variable cost-share demonstration model—to leverage funding more effectively and enable substantially increased demonstrations. In 2010–2012 the program expanded again to include military bases in California—while documenting energy use reductions resulting from already-achieved deployments of the technologies through major subsidy programs. In 2012–2014, the program refocused on its original partner University of California and California State University campuses, continuing demonstration activities while supporting pilot-scale deployments of demonstrated technology.

A summary of recent program projects highlights the early-2012 through mid-2014 demonstrations and key pilot scaled deployments among the more than 100 individual projects and more than 30 PIER technologies in the State Partnership for Energy Efficient Demonstrations portfolio (Table 1).

Table 1: SPEED Program Projects: March 2012 - July 2014

		UC/CSU	CSU		UC							Special Sites
		IOU Partnership / UCOP	Long Beach	2014 CHES Conference-San Diego State	San Francisco	Davis	Berkeley	Los Angeles	Santa Barbara	2012 CHES Conference-Davis	2013 CHES Conference-Santa Barbara	Beale Air Force Base Dining Facility
Lighting	Adaptive Corridor Lighting (Next Generation)				X						X	
	Adaptive Office Lighting										X	
	Smart (Bi-Level) Parking Luminaires				X							
	Networked Wall Pack Lighting (LED)									X		
	Networked Adaptive Site Lighting									X	X	
	Networked Post Top Collar/Path Luminaires										X	
HVAC	Large System Duct Sealing					X						
	Advanced Retrofits for Rooftop Package Units		X	X								
	New Construction Case Study					C						
	Personal Comfort Systems						X					
	Follow-on to Beale AFB Whole Building Retrofit											C
	Case Study for Condenser Air Pre-Cooling											C
	Shut-the-Sash Programs for Lab Fume Hoods					X		X				
Pilot Scaled Deployment	Monitoring-Based Commissioning (MBCx)	O										
	Benchmark-Based Energy Performance Targets	X										
	Demand Controlled Kitchen Ventilation	X										
	Adaptive Corridor Lighting	X										
	Adaptive Site Lighting	X										
	Zero Net Energy Retrofit								I			

C = carryover project; CHES = California Higher Education Sustainability; CSU = California State University; HVAC = Heating, Ventilation, and Air-Conditioning; IOU = Investor-Owned Utility; I = in progress; UC = University of California; UCOP = University of California Office of the President

Program Results and Accomplishments

The program's new, interactive market adoption process supports the PIER program efficiency areas, built demonstration partnerships that have increased program effectiveness, and created a variety of tangible benefits to California. The major accomplishments are:

1. **Technologies developed with PIER funding have successfully entered the market**. By getting technologies deployed on University of California and California State University campuses at scale, the Program created a market pull, so that technologies became more available for other sectors of the commercial buildings market. These and other organizations are specifying PIER program technology and other new technologies in their retrofit and new construction projects.

2. **Valuable feedback provided to the PIER RD&D Program and manufacturer product development cycles**. Those results often 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 the testing and analysis and reported back to the Public Interest Energy Research program. Examples include adaptive and networked lighting systems, as well as the discharge air regulation technique and data center automation software and hardware systems.

3. **Utilities include data 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 and Western Cooling Efficiency 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 many of the technologies in the program portfolio.

4. **Results have influenced codes and standards.** Program demonstrations have shown codes can have more stringent energy efficiency requirements because products are available to meet them. Results of the demonstrations were provided to the Energy Commission's Codes and Standards group for developing revisions to Title 24. The 2013 Title 24 and Title 20 code proposals adopted a remarkable amount of program-demonstrated technology. Examples include occupancy- and daylighting-based bi-level switching in many interior and exterior scenarios, dimmable electronic ballasts and other adaptive lighting technology, lower-power densities for offices, and demand-controlled ventilation for commercial kitchens. ASHRAE 90.1 standards have already adopted bi-level lighting controls for both interior stairwells and exterior parking and lighting.

   Technology demonstrated by the program now figures prominently in measures included in the 2013 update to California's Title 24 Building Energy Efficiency Standards. Estimated statewide annual savings from a partial set of these measures—demand controlled commercial kitchen ventilation and certain lighting measures—totals more than 160 million kWh per year and more than 700 thousand therms per year, with avoided energy costs of over $20 million per year.

5. **More manufacturers enter the market**. Products similar to, or even better than, the PIER program technologies have been developed and introduced to the market. When this happens, the influence of the Energy Commission's program is leveraged or magnified, and the benefits are more available to state organizations and to the public. For example, many different manufactures are now making products similar to the integrated classroom lighting system, bi-level stairwell fixtures, and smart exterior lighting fixtures. One key example of the market influence of the program has been the development of "smart" (adaptive) occupancy-based and daylighting controls for parking and exterior fixtures along with the introduction of light-emitting diode (LED) technology. Many manufacturing partners now produce a large array of adaptive exterior fixtures and are shifting the market to these new technologies.

6. **Numerous success stories available.** Numerous case studies or fact sheets showcase the successful PIER program products, much earlier than for a typical commercialization process. These have contributed to faster technology adoption by California's university campuses, utility incentive programs, and codes and standards. Exposure to the verified performance of technology innovations has led to adoption by the broader commercial building market as well.

7. **Market aware of options previously not available.** The program's market communications target raising market awareness as another step in promoting the technologies. Documented demonstration results and case studies on a significant number of buildings help to build confidence in the new technologies and reduce early adopter risks. The program has produced a large and varied number of technology transfer and market communication materials and activities, including: case studies and business cases, dozens of major presentations, a website, training and education efforts, and published papers.

8. **Successful new companies creating jobs and investment opportunities.** Several new companies have evolved out of the PIER program's research, development, and demonstration activities, and many more have added products and jobs. Some of these companies are thriving, while others have been usurped by more competitive rivals.

Benefits to Californians

Overall, the SPEED program has proven to be effective in leveraging research and development investments, providing programmatic assistance to help the PIER program technologies move through the valley of death and into the marketplace. Demonstration partnerships not only provide field verification but also provide 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 help the companies associated with the research, demonstration, and development program overcome many of the market introduction barriers.

Documented reductions in energy use from distribution of demonstrated technologies are a good indicator of program effectiveness. The value of the documented annual energy savings to California consumers is now more than double the total investment in the program, and is increasing steadily.

One measure of program benefits to California is the statewide energy savings resulting from the market potential of the demonstrated technologies in retrofit applications. Estimated energy savings from a partial set of program technologies based on 25 percent market penetration is approximately $558 million each year (Table 2).

Table 2: Market Potential of SPEED Program Technologies (Partial)

	Annual Electricity Savings (million kilowatt-hours, kWh	Annual Natural Gas Savings (million therms)	Reduction in Annual Carbon Emissions (metric tons of carbon dioxide equivalent, CO_2e)	Annual Monetary Savings ($millions)
25% Market Penetration for • Interior and Exterior Lighting • HVAC Package Units • Wireless HVAC Controls • Personal Comfort Systems • Kitchen Demand-Controlled Ventilation • Wireless HVAC Controls for Data Centers • Monitoring-Based Commissioning	3,567	97	1,526	558

Notes: Assumed market penetration is 25% of all commercial and institutional floor space in California.
Other assumptions: 0.000283 of CO_2e per kWh, 0.0053 metric tons of CO_2e per therm, $0.1418 per kWh ($0.10 per kWh for exterior lighting), $0.705 per therm

Further benefits are from program effectiveness in coordinating demonstrations with large university campuses. The advantage of working with campuses is the potential to both demonstrate technologies in multiple buildings and demonstrate more than one technology per campus. Less time was devoted to finding test sites, less time was spent coordinating agreements, and fewer trips were needed to test sites. As a result, the program was able to do more testing with less money than is typically possible. Currently the energy savings achieved and anticipated by the SPEED Program through working with various university campuses is $31 million per year (Table 3).

Table 3: SPEED Achieved or Targeted Savings Using PIER Technologies (Partial)

	Annual Electricity Savings (million kWh)	Annual Natural Gas Savings (million therms)	Annual Energy Cost Savings ($millions)
• UC/CSU/IOU Partnership • UC Davis Smart Lighting Initiative • Third-Party Programs (SCE & PG&E) • State Energy Program (SEP) / American Recovery and Reinvestment Act (ARRA)—Energy Technology Advancement Program Advancement Program • Enlighted Installations			
• Interior and Exterior Lighting • Wireless HVAC Controls • Demand-Controlled Kitchen Ventilation • Wireless HVAC Control for Data Centers • Monitoring-Based Commissioning			
Total Savings Achieved by Deployments To Date	**128**	**5.6**	**22**
• UC/CSU/IOU Partnership • UC Davis Smart Lighting Initiative			
• Interior and Exterior Lighting • Demand-Controlled Kitchen Ventilation • Monitoring-Based Commissioning			
Total Additional Targeted Savings (In Progress)	**55**	**1.5**	**9**
Total Savings Achieved and Targeted	**183**	**7.1**	**31**

Notes: Assumptions are $0.1418 per kWh, $0.705 per therm

The SPEED program's nimble approach is effective in maximizing distributing technology and applying knowledge in diverse market settings. The program has been effective in facilitating new technology integration into utility energy efficiency and economic stimulus programs, and both California and national codes and standards. Multiple technologies are now benefitting California energy consumers earlier than they would have otherwise.

The University of California system will continue to be a leader in scaled deployment of new technology—with substantial incentives offered by the UC/CSU/IOU Partnership, along with a loan program fully integrated into system and campus debt management. The California State University system and local governments have also achieved substantial scaled deployment of PIER program technologies and may be good venues for SPEED activity, but this progress has been more dependent on transient economic stimulus funding.

The SPEED Program has also accelerated the market adoption of new energy efficiency technology. The case studies provide manufacturers with feedback crucial for developing new technologies and product lines with greater market potential. The program has also been successful in stimulating new manufacturers to develop products based on demonstrated technologies. It has supported the evolution of codes and standards tracking new technology, as well as compelled 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, and has addressed the goals of the California Long Term Energy Efficiency Strategic Plan.

CHAPTER 1:
The SPEED Program

The Public Interest Energy Research (PIER) program advances science and technology in the fields of energy efficiency, renewable energy, advanced electricity generation, energy-related environmental protection, transmission and distribution, and transportation. To accomplish this, PIER enlists businesses, utilities, energy companies, public advocacy groups, and world-class scientists at California's universities and national laboratories.[1] These research, development, and demonstration (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 (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 Program). The California Institute for Energy and the Environment and its partner organizations installed, monitored, evaluated, and reported on the performance of a group of technologies, most of which 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:

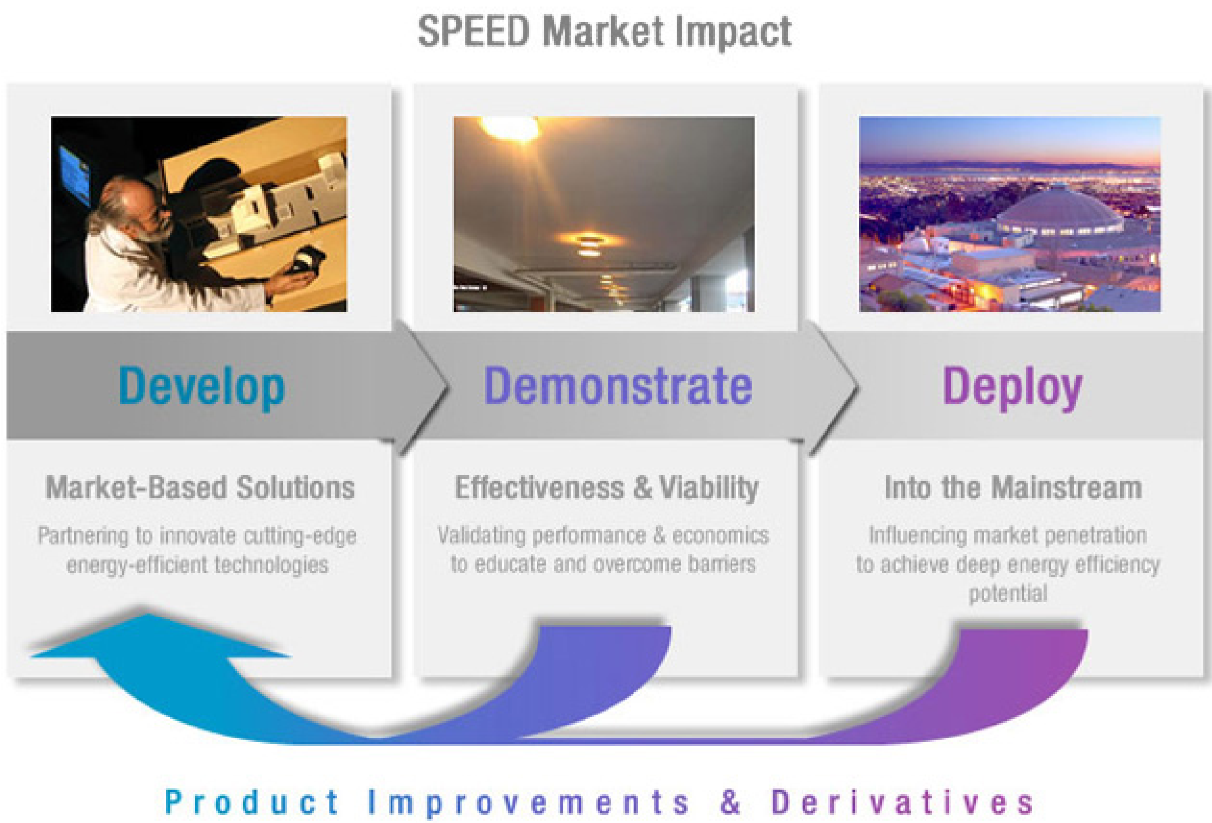
- Transfer PIER-sponsored technologies primarily to the existing institutional and commercial sectors, including incorporation into codes and standards.
- Gain working experience with innovative technologies so that more informed decisions can be made regarding their use in relevant, large-scale applications.
- Gain new knowledge of the energy efficiency of institutional and commercial facilities in California.

1 PIER. California Energy Commission. Homepage. http://www.energy.ca.gov/research/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 is now hosted by the Berkeley campus.

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, enabling them to become "mainstream (Figure 1)."

Figure 1: The Innovative SPEED Market Transformation Process



At about the same time the Program began, a pilot energy efficiency partnership was formed between California's four investor-owned utilities (IOUs), UC, and CSU. The UC/CSU/IOU Energy Efficiency Partnership (UC/CSU/IOU Partnership) was designed to provide a sustainable energy-management framework for the 33 university campuses served by the IOUs.[3] In particular, this partnership provides UC and CSU campuses with resources and funding opportunities for energy efficiency projects. Campus facility and energy managers began to select appropriate energy-efficient technologies, including technologies demonstrated through the Program, and finance the improvements through the UC/CSU/IOU Partnership. In addition, educational services for campus personnel were developed with curricula, including substantial PIER technology content. Thus, the UC/CSU/IOU Partnership provided an avenue to disseminate information generated during the Program and assist campuses financially with future energy efficiency projects.

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

The Program was extended for another three years in 2007. The extended program was renamed the State Partnership for Energy Efficient Demonstrations (SPEED).[4] It was expanded to include community college districts, state agencies, local governments, special districts, and Silicon Valley Leadership Group organizations.

Follow-on funding was provided for the period from July 2010 through February 2012 (2010–2012). The extended program was further expanded to included military bases in California.

Follow-on funding was again provided through December 2014. This report covers this fourth phase of effort, which returned to a focus on UC and CSU campuses, with a new emphasis on supporting technology deployment.

1.1 Program Goals and Team Members

The Program transfers 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 in early phases, CIEE had the Architectural Energy Corporation (AEC), the California Food Service Technology Center (FSTC), and the California Lighting Technology Center (CLTC) work with campuses (and later, with others) to demonstrate PIER and other key new technologies. This process often involves matching appropriate technologies with host sites, establishing baseline facility energy efficiency performance, and evaluating the new technologies relative to the baseline performance. Lawrence Berkeley National Laboratory (LBNL), the Western Cooling Efficiency Center (WCEC), and other RD&D organizations were later added as team members.

From 2010–2012 the CLTC and WCEC remained core team members. The Center for the Built Environment (CBE) at UC Berkeley was added in conjunction with planning for demonstration of low-energy personal comfort systems (PCS). The California State University at Sacramento and the FSTC participated to organize on-site activities for the comprehensive retrofit of the Contrails Inn Dining Facility on Beale Air Force Base (AFB).

From 2012–2014, the team consisted of CIEE, CLTC, WCEC, and CBE.

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

General Program objectives include the following:

- Verify technology performance.
- Continue to provide both initial and strategic demonstrations for PIER technologies.
- Analyze technology integration with other building systems and components.

4 State Partnership for Energy Efficient Demonstrations. http://www.partnershipdemonstrations.org/.

- Improve Title 24 and Title 20 energy efficiency standards.
- Collaborate with California utility programs and other energy efficiency industry partners.
- Identify institutional usage patterns.
- Document the retrofit process.
- Survey and document building operator responses to new technologies.
- Identify potential product modifications, and make recommendations based on users' responses to demonstrated technologies.
- Build new partnerships with UC, CSU, and sometimes other partner organizations for future technology transfer activities.
- Develop a technology transfer and outreach portfolio including; case studies, guidebooks, specifications, presentations, and business cases.
- Develop a new model for market adoption that accelerates the commercialization path for cutting-edge best practice deep energy efficiency technologies.
- Explore comprehensive, whole-building, and zero net energy retrofit approaches.
- Provide assistance with pilot-scale deployment of demonstrated technologies.
- Document achieved and targeted savings of scaled deployments and programs targeting demonstrated technology.

A specific program objective for 2012–2014 was to:

- Explore development of business cases as a technology transfer tool for accelerating market adoption of demonstrated technology.

1.2 Report Organization

This final report covers Program activities from March 2012 through July 2014. Information about the first eight years of the Program (2004–2012) is also provided for context where appropriate. This report describes Program impacts and accomplishments, serves as an index and concise reference to Program activities, and provides an index to the dozens of documents detailing Program elements. The major chapters of this report and their intent are:

- Chapter 2, Technology Portfolio, describes the technologies 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 in 2012–2014, with summary tables of all projects conducted by the Program.

- Chapter 5, Outreach, 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, Program Impacts, provides estimates of the potential energy savings from statewide adoption of demonstrated technologies in retrofit scenarios, a listing of major deployment programs using the technologies, and information about energy savings achieved or targeted by the programs to date (updating information provided in the 2004–2010 and 2012–2014 Working Draft Program Reports). This chapter also discusses market adoption milestones and other Program achievements.
- Chapter 7, Conclusions and Next Steps, summarizes the Program's impact and discusses potential for extending successes in getting new technology to market.

The report refers to dozens of Program documents referenced as Attachments. These include technical reports, case studies, business cases, and other program documents. This report also references the Working Draft reports from 2004–2010 (Johnson et al. 2011) and 2010–2012 (Brown et al. 2012).

CHAPTER 2: Technology Portfolio

This chapter describes the active technology portfolio for the SPEED Program. The portfolio includes the following elements:

- Previously demonstrated technologies that are achieving substantial market penetration in scaled deployments (e.g., bi-level or adaptive interior and exterior lighting, monitoring-based commissioning).
- Technologies demonstrated from March 2012 through July 2014 (e.g., personal comfort systems and exterior wall pack lighting).

New technologies added to the Program Technology Portfolio for 2012–2014 include:

- Networked Site Lighting
- Advanced Rooftop Package Unit (RTU) Retrofits
- “Shut-the-Sash” Programs for Laboratory Fume Hoods
- Whole-Building Benchmark-Based Building Energy Performance Targets

New technologies that were introduced in projects carrying over from 2010–2012 include:

- Low-Energy Personal Comfort Systems
- Occupancy Sensing Networked Thermostats
- Evaporative Pre-Cooling of Condenser Air

In addition, the Program continued to explore combinations of technologies in a comprehensive design or retrofit scenario, including a zero net energy retrofit project.

At the beginning of the Program in 2004, CIEE, other Program team members, and PIER Buildings Energy Efficiency 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 (Johnson et al. 2011). 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 a 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 once an actual demonstration is considered (e.g., if enough product is available for the anticipated demonstration).

The technologies were divided into two groups: those that were market-ready and those still involved in beta testing. This distinction was made so that the campuses would understand the risk in selecting certain technologies over others.

The Program also addressed technologies that do not fit into typical demonstration projects (e.g., 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 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, PIER's Industrial/Agriculture/Water (IAW) End-Use Efficiency program began to participate in the Program. The Program demonstrated selected IAW technologies with a few, such as wireless control for cooling in data centers, remaining in the Program portfolio.

In 2010–2012 and again in 2012–2014, the Program continued to add technologies to the portfolio based on individual assessment by CIEE, the CLTC, or the WCEC. The Program has also removed technologies from the portfolio as they become superseded by new technology or as manufacturers discontinue products or fail to make progress toward market adoption (e.g., hybrid vanity lighting fixtures).

The IAW area did not directly participate during 2010–2014, so no new technologies were added from that sector. The one exception is "Shut-the-Sash" programs for laboratory fume hoods, which is on the cusp of the IAW and Buildings Energy Efficiency areas.

2.1 Lighting

The pace of innovation in lighting technology accelerated in the period leading up to and including the 2012–2014 phase of the Program. Advances in adaptive lighting controls, pioneered by PIER and CLTC research and followed by CLTC and SPEED demonstrations, resulted in many new options in the market. The market for adaptive lighting controls has now been strongly supported by measures in the 2013 update of the California Title 24 Building Energy Efficiency Standards.

The synergy between lighting control and dimming capability of solid-state light-emitting diode (LED) technology has resulted in additional innovation and a trend toward LED lighting becoming dominant in the market. Advances in wireless control technology have provided an additional technology driver toward even more flexibility in control, with energy use required to provide quality lighting dropping to a small fraction of typical levels before the year 2000.

The strong, early influence of the PIER and SPEED programs often manifested in derivative products coming to market after feedback from SPEED demonstrations. This phenomenon has evolved into evolution of entire classes of products, as bi-level stairwell lighting lead to bi-level exterior lighting, then to multi-level interior and exterior lighting control, then to continuous dimming capability in many applications, and finally, to networked applications.

2.1.1 Efficient Sources

2.1.1.1 Light-Emitting Diode Technology

Light-emitting diode technology is developing rapidly, with steadily improving quality and durability. At the same time, prices are dropping rapidly, at a pace some have compared with another solid-state technology: semiconductors for computing applications. This technology has become the most efficient and longest life choice for many applications, and is becoming the preferred technology in many new construction and retrofit scenarios. The newer organic LED technology is already used in one major manufacturer's products.

Light-emitting diode technology has unique properties and capabilities that allow radical improvements in the design of lighting systems and provide synergies with control technology. Many predict that within five years LED technology will dominate virtually all applications.

The SPEED program has demonstrated multiple LED-based products, usually in conjunction with adaptive control capability. LED-based options are included in business cases developed by the Program for adaptive corridor and adaptive exterior lighting. Please see Sections 4.3.1.2, 4.3.1.3, 4.3.1.6, 4.3.1.7, as well as Attachments I, II, III, IV, and V for details of these efforts.

2.1.1.2 Induction Technology

Induction technology may be able to continue to compete with LED technology in certain applications, bolstered by the recent introduction of digitally controlled induction lighting products. However induction technology cannot dim as low as LED technology and the substantial price advantage it once had has now disappeared. There was no direct Program activity related to this technology in 2012–2014.

2.1.1.3 Dimming Fluorescent Ballast Technology

Dimming fluorescent ballast technology will remain important in situations where legacy fluorescent luminaires are difficult to change out with edge-lit or other LED-based luminaire designs. Retrofits with adaptive controls to achieve granularity down to the luminaire level, including new dimming fluorescent ballasts, will remain a substantial part of the market for the near future.

Costs for dimming fluorescent ballasts are already down due to competition from LED technology and in advance of the new 2013 Title 24 requirement for either LED technology or dimming fluorescent ballasts for many applications. It will be interesting to see what fraction of the new construction market is retained by fluorescent technology with dimming ballasts, and for how long, as LED technology continues to dramatically increase in popularity.

For 2012–2014 the SPEED business case for adaptive corridor lighting included scenarios with dimming fluorescent ballasts. Please see Section 4.3.1.6 and Attachment IV for more information.

2.1.2 Task/Ambient and Other Layering Approaches

Task/ambient lighting and other layering approaches are another component of smart lighting design that enables very low energy use. These approaches are employed extensively in zero net energy and other deep-efficiency projects. For example, by combining high-quality ambient luminaires, which provide a lower, uniform, diffuse, light level for general office space with energy-efficient, high-quality personal task lighting, the lighting load is reduced by a large margin. Past PIER and SPEED program efforts have led to a robust market of products employing task/ambient approaches in offices and other applications. There was no Program activity focusing on this technology in 2012–2014, though some demonstrations incorporated the concept.

2.1.3 Controls

Advances in control technology are allowing the tuning of lighting systems with granularity down to the luminaire level and with ever more adaptive modulation responding to occupancy and availability of daylighting. Previous SPEED Program efforts led to the incorporation of adaptive lighting requirements in the 2013 update to Title 24. In 2012–2014, the SPEED program continued to demonstrate lighting controls that outperform the minimum requirements of 2013 Title 24, further reducing energy use by almost half in many scenarios. Please see Sections 4.3.1.2 and 4.3.1.3. In addition, in 2012–2014 the Program introduced business case documents, including one for adaptive corridor lighting. Please see Section 4.1.3.6 and Attachment IV for more information. Finally, the SPEED program continued to support the adoption of advanced lighting controls with measurement and verification protocols accounting for the full savings available from for adaptive lighting retrofits. Please see Section 5.2.4.2 for more information.

2.1.3.1 Networked Controls

Networked controls provide a wide range of benefits for optimizing and maintaining lighting systems. These include control, energy monitoring, and reporting with a computer or smart device user interface. Networked controls also enable tuning or trimming lighting levels with substantial savings in addition to those available from basic occupancy and daylighting control.

In 2012–2014, Program demonstrations emphasized networked exterior and interior controls providing support to campuses as they adopt these systems. Both UC Davis and UC Irvine have campus-wide networked controls for their exterior lighting. The UC Davis campus-wide networked controlled lighting retrofit won the 2012 UC Best Practice Award for Lighting Retrofits. Several campuses are adopting networked controls in interior applications, with CSU Dominquez Hills and UC Santa Cruz winning 2014 Best Practice Awards for networked interior lighting projects. Please see Sections 4.3.1.1, 4.3.1.2, and 6.8.1, as well as Attachments II, III, and IV for more information.

2.1.4 Exterior and Garage Applications

Light-emitting diode technology is rapidly becoming the standard choice for most exterior lighting applications. Reduced maintenance needs and controllability of LED technology is driving this shift, along with continued improvements in energy performance and lowering of costs. Program demonstrations have helped facilitate this accelerated market adoption. Adaptive exterior lighting incorporating occupancy-based control is becoming a popular energy efficiency retrofit, as well as a required feature for new construction in the 2013 update to the Title 24 standards. Program activities in 2012–2014 focused on networked control and a business case for efficient exterior lighting. Please see Sections 4.3.1.1 and 4.3.1.7, as well as Attachments II and IV for more information.

2.1.4.1 Parking Lot and Area Lighting

The PIER and SPEED programs have been instrumental to the development and addition of fixture-integrated controls, now with networking options, to parking lot and area luminaires. Program demonstrations have accelerated widespread implementation of energy efficiency retrofits of parking lot and area lighting. Program activities for 2012–2014 included support for custom fixture retrofits at UC Santa Barbara, a demonstration at UC San Francisco, and a business case. Please see Sections 4.3.1.2, 4.3.1.4, and 4.3.1.7 as well as Attachment II and IV for more information.

2.1.4.2 Parking Garage Lighting

The PIER and SPEED programs have also led the rapid adoption of adaptive lighting for parking garages, including migration toward LED technology. There was no direct program activity for this application in 2012–2014. Garage applications were included in the addition of controls requirements for interior spaces in the 2013 upgrade of Title 24.

2.1.4.3 Pathway Lighting

The accelerated migration to adaptive control and LED technologies has also included pathway lighting. The Program continued its work with pathway lighting in 2012–2014 with support for a retrofit project including custom fixtures, as well as documentation of a campus-wide networked exterior lighting controls, including pathway lighting. Please see Sections 4.3.1.1, 4.3.1.2, and 4.3.1.7, as well Attachments II and IV for more information.

2.1.4.4 Building Perimeter Security Lighting

Building perimeter security lighting is another exterior lighting application following the trends toward adaptive control and LED technology. In 2012–2014, the Program supported an adaptive LED wall pack (i.e., a wall-mounted area lighting fixture) retrofit project including integration into a campus-wide exterior lighting control network. Please see Section 4.3.1.1 and Attachment II for more information.

2.1.4.5 Street Lighting

Street lighting technology is also migrating toward adaptive control and LED technologies. In 2012–2014, the Program continued its series of street lighting demonstrations with support for a retrofit project at UC Santa Barbara, including integration into a network control system. Please see Section 4.3.1.2 and Attachment II for more information.

2.1.5 Interior Lighting Applications

Adoption of LED technology for interior lighting is closely following the trend for exterior lighting. Light-emitting diode technology has already become the market standard for downlighting and display lighting, and is rapidly gaining market share in most other applications. Adaptive control technology has leapt forward from the original application to bi-level stairwell fixtures, becoming a ubiquitous feature for most new and many retrofit installations. Basic adaptive capability is required for most interior spaces in the 2013 update to Title 24. Even more-advanced technology can go far beyond Title 24 requirements, providing deep efficiency with granularity of control down to the luminaire level, as well as offering tuning and trimming capability.

In 2012–2014, Program efforts for interior lighting focused on demonstrating deep energy efficiency from networked adaptive LED technology, a business case for adaptive corridors, and applications associated with a zero net energy building retrofit. Please see Sections 4.3.1.1, 4.3.1.2, and 4.3.1.6, as well as Attachments II, III, and IV for more information.

2.1.5.1 Classrooms and Conference Rooms

The integrated classroom lighting system (ICLS) pioneered by the PIER and SPEED programs has followed the LED trend, with new product lines now incorporating LED technology for even greater energy efficiency than that achieved with the original fluorescent implementations. Since there was no change to the maximum lighting power density allowance for classrooms in the 2013 update to Title 24, LED-based ICLS now offers the ongoing opportunity to be much more efficient than code (for organizations with reach goals striving to improve upon code-required performance). Several manufacturers now market ICLS-type products to schools across the country. There was no direct Program activity for this application in 2012–2014.

2.1.5.2 Stairwells

The PIER and SPEED programs demonstrated the original bi-level stairwell lighting technology supported by the New York State Energy Research and Development Authority (NYSERDA), and then extended the concept to adaptive lighting for exterior, garage, and interior applications. Newer adaptive stairwell lighting product offerings have come full circle, now incorporating LED technology. As with most other lighting applications, bi-level stairwell lighting is required by the 2013 update to Title 24. Adaptive LED stairwell technology is becoming a popular choice for both retrofit and new construction applications. There was no direct Program activity for this application for 2013–2014.

2.1.5.3 Corridors

Corridors are an ideal application for occupancy-based adaptive lighting controls. In 2012–2014, the Program supported this application with a demonstration at UC San Francisco, and a business case focusing on funding options available to UC and CSU campuses. The Program explored multiple levels of technology for adaptive corridor lighting, including network control and LED technology options. The Program also developed measurement and verification protocols for corridor lighting projects that will allow the full savings from typically low occupancy rates to be captured in savings accounting associated with financing options (Sections 4.3.1.4, 4.3.1.6 and 5.2.4.2, and Attachments II, III and IV for more information).

2.1.5.4 Offices

Office lighting applications can greatly benefit from adaptive lighting control and task/ambient strategies. The general trend toward LED technology compliments both of these strategies. In 2012–2014, the PIER and SPEED programs continued providing leadership in office lighting with a demonstration of deep energy efficiency from networked luminaire-level adaptive lighting controls combined with state-of-the-shelf[5] LED luminaires. Tuning of lighting levels is the most important energy efficiency measure enabled by the integrated technology. This enabled reduction of lighting use down to as low as 0.5 kilowatt-hours (kWh) per gross square foot of floor area for up to nearly 90 percent energy savings compared to some existing systems. The Program also supported the implementation of adaptive LED office lighting as a part of a zero net energy retrofit project. Please see Sections 4.3.1.2 and 4.3.1.3, as well as Attachments II and III, for details.

2.1.5.5 Downlighting

Supported by the PIER and SPEED programs, LED-based recessed downlight products have matured in quality, price, and performance to become the preferred alternative for both retrofit and new construction applications. There was no direct Program activity for this technology in 2012–2014.

2.1.5.6 High-Bay Lighting

High-bay lighting products are now available with glare control and integrated occupancy and daylight harvesting controls. In 2012–2014, the Program supported the retrofit of four gymnasiums with networked LED lighting as a part of the zero net energy retrofit of the UC Santa Barbara Recreation Center. Please see Attachment V for more information.

2.2 A Process Success Story: From Demonstration to Deployment to New Standards to the Next Generation of Technology

Lighting accounts for about 35 percent of energy use in California's commercial buildings. But what exactly is being lit, day in and day out, and at what cost, in both wasted dollars and wasted energy? In buildings of every type, corridors, stairwells, lobbies, service rooms, and library stacks are brightly lit for long hours, sometimes 24/7, even though people occupy these "secondary spaces" infrequently or intermittently. Installing adaptive, multi-level lighting—systems that detect the presence of people and turn off, dim, or raise the lights accordingly—is an effective way to save energy, shed load during peak demand, and realize a substantial return on a manageable investment in energy efficiency.

Progress in implementing adaptive corridor lighting is an excellent example of how Public Interest Energy Research funded research, development, and demonstration lead effectively to pilot-scale deployment, widening use, and new standards and policies to benefit California—precisely the continuum of progress and market transformation that the State Partnership for Energy Efficient Demonstration program is designed to foster. Adaptive corridors are a "derivative product" of a cascade of successfully sponsored activities, launched in 2004–2006 with demonstration of bi-level stairwell fixtures developed by the New York State Energy Research and Development Authority on 10 University of California and California State University campuses. These demonstrations resulted in retrofit projects around the University of California and California State University systems. These activities were followed by demonstration of a portfolio of bi-level exterior parking, garage, and pathway lighting fixtures

[5] Latest commercially available technology.

in 2010; again leading to retrofits using this technology on many University of California and California State University campuses and at state facilities.

In a continuation of technology progression, work began in 2008 on adaptive lighting for corridors and other secondary spaces. The California Lighting Technology Center at UC Davis led this effort, working with manufacturing partners to develop and field-test prototype systems. The program demonstration process put these new technologies into practical use, documented energy and cost savings, supported award-winning retrofit projects, and ultimately enabled their establishment as a new California standard for corridor lighting.

The Demonstration Process for Adaptive Corridors

At UC Davis, the California Lighting Technology Center's home campus, keeping corridors lit accounted for 25 percent of lighting energy use. By monitoring occupancy in corridors (and stairwells), the California Lighting Technology Center learned that these areas are vacant from 64 - 94 percent of the time. Existing lighting in these spaces was provided through non-dimmable ballasts, operated by wall switches or from panel boxes—standard for campus buildings, yet incapable of adapting to changes in occupancy and lighting need. The first adaptive corridors demonstration was carried out in UC Davis's Bainer Hall, an engineering building constructed in 1966. Three different adaptive lighting systems were installed for demonstration, assembled from components marketed by several manufacturers. These systems each delivered bi-level lighting by pairing occupancy sensors with dimmable light sources in corridors. The evaluations conducted through the demonstration gauged energy savings and occupant response.

Scaled Deployment

The successful demonstration of the three options at UC Davis led quickly to a multi-technology project at California State University at Long Beach—with award-winning results. Combinations of bi-level and other energy-efficient lighting were installed in corridors, stairways, parking garages, and other areas of 24 campus buildings over two years. The changes resulted in an estimated savings of 600,000 kilowatt-hours of electricity and $72,000 per year, in addition to cutting the campus's greenhouse gas emissions. The project was funded by the Energy Technology Assistance Program—part of the American Recovery and Reinvestment Act State Energy Program—as well as by the UC/CSU/IOU Energy Efficiency Partnership. The effort earned CSU Long Beach the Best Practice Award for Lighting Design and Retrofit, presented at the California Higher Education Sustainability Conference in July 2011.

Success with initial adaptive corridor installations informed an additional "scaled deployment" in 11 CSU Long Beach buildings. The campus retrofitted the buildings with Adura bi-level, wireless corridor lighting controls; one of the three solutions successfully demonstrated by the California Lighting Technology Center. A second scaled-up deployment of adaptive corridors is in the works at the University of California, San Francisco, where a major project aims to transform millions of square feet of corridors throughout the campus (excluding Medical Center facilities). Again, the program is providing support by demonstrating the latest available technologies on the campus to allow informed decisions for the larger project.

New Standards and Other Derived Benefits

Title 24, California's Energy Efficiency Standards for Residential and Nonresidential Buildings, is a key driver in accelerating market penetration of new energy efficiency technologies. Following quickly on its successful demonstration and deployment, multi-level lighting with occupancy-based controls for corridors was proposed and adopted as a standard in the standard's 2013 update, which went into effect July 1, 2014.

Just as adaptive corridors are a derivative of earlier lighting technologies demonstrated through the program, the success with adaptive corridors is spawning additional applications in other types of common interior spaces. Adaptive lighting control systems for other interior spaces have already been incorporated into the ASHRAE/IES 90.1 energy standards, as well the 2013 Title 24 update. This progression is illustrative of a substantially quickened pace in adopting new lighting technologies and incorporating their demonstrated benefits into new standards. The program is a major driver of this acceleration, and an effective component of our urgent efforts to meet energy efficiency and climate protection goals.

Next Generation

In 2013, the Program demonstrated the next generation of adaptive corridor and office lighting with luminaire-level control of edge-lit light-emitting diode (LED) technology in the Student Services space at UC Santa Barbara. This deep efficiency retrofit achieved a low 0.5 kilowatt-hour per year per gross square foot of lighting energy use intensity. Similar technology was installed as the lighting component of the zero net energy retrofit of the Recreation Center at UC Santa Barbara. Competition in the adaptive controls market has led to the purchase of the original program partner Adura by another company, as well as the emergence of strong new brands.

2.3 Heating, Ventilation, and Air-Conditioning (HVAC): General Applications

2.3.1 Technologies with 2012–2014 Program Activity

2.3.1.1 Large Duct System Sealing

Forced air duct systems often leak by 20 percent or more, contributing to poor air balance, loss of conditioned air, short-circuiting between supply and return systems, and increased fan power. 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 (Figure 2). 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

Figure 2: Forced Air Sealing Equipment

walls and edges and nucleate into a seal. Lawrence Berkeley National Laboratory licenses the technology to Aeroseal. It is most appropriate in supply, return, and central exhaust systems that leak by more than 10 percent. Fan energy savings can easily exceed 50 percent, and energy savings for heating and cooling can amount to 30 percent or more, depending on the application. See Section 4.3.2.1 and the Technical Report in Attachment III for description of a project evaluating duct sealing in the Art Building at UC Davis.

2.3.1.2 Advanced Thermostat Controls

A thermostat is generally the single human interface with a building's mechanical system, and decisions made at this interface affect comfort as well as energy consumption. Advanced thermostat controls use various techniques to improve performance, such as being networked or having occupancy-sensing capability; employing an improved, more engaging user interface; or using advanced algorithms (e.g., those with adaptive recovery times or that learn the space load profile or users' schedules and preferences) (Figure 3). Occupancy sensing may be used to relax space temperatures to a reasonable setback when nobody is present, adaptive algorithms may be used to learn user schedules and comfort, and demand response capabilities can interface with electric utility programs that address peak demand. See Section 4.3.2.2 and the Technical Report in Attachment III for evaluation of advanced thermostat controls in dormitories at UC Davis.

Figure 3: Advanced Thermostat Control

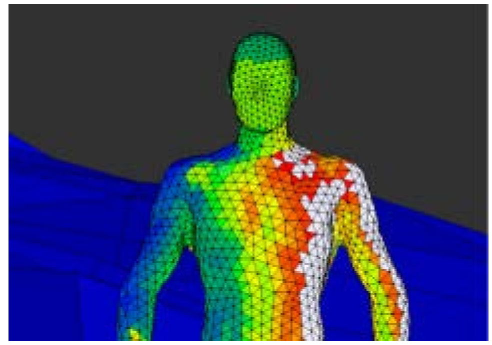
2.3.1.3 Advanced Retrofit Controls for Packaged Rooftop Air Conditioners

Variable-volume operation has been a standard for large built-up air handlers for many years, but recent advances have made this technique appropriate for application in smaller packaged rooftop units as well. Moving only as much air as is needed to satisfy ventilation and conditioning loads can achieve great fan energy savings. Variable speed control for packaged rooftop equipment can be applied in concert with other rooftop package unit retrofits, such as demand controlled ventilation, advanced economizer controls, and evaporative condenser-air coolers (Figure 4). Demonstrations of one popular package of advanced retrofit controls took place at CSU Long Beach and San Diego State University. More information about these demonstrations can be found in Section 4.3.2.6 and Attachment II.

Figure 4: Rooftop Air Conditioner

2.3.1.4 Low-Energy Personal Comfort Systems

Figure 5: Heat Map of a Human with Personal Comfort Control



Analogous to task-ambient lighting techniques, low-energy personal comfort systems provide local heating, cooling, and/or air movement with individual control. The ambient space temperature can be relaxed, while maintaining or improving air quality and comfort. Personal control can be accomplished by various methods including low-energy heating and cooling capability embedded in ergonomic chairs, local heating with foot or leg warmers, and personal fans or ceiling fans. Figure 5 shows a heat map of a human feeling the effects of personal comfort control. Studies indicate that in appropriate applications, these systems can eliminate a substantial fraction of the energy used for heating and cooling. See Section 4.3.2.7 and Attachments II and III for information on demonstrations of this technology on the UC Berkeley campus.

2.3.1.5 Radiant Heating and Cooling with Dedicated Outside Air System (DOAS)

Figure 6: Gallagher Hall at UC Davis

Radiant heating and cooling systems use water and radiative surfaces to distribute thermal energy in a building. Water is circulated through panels, slab ceilings, and sometimes slab floors—large exposed surfaces that exchange heat directly with occupants as wells as with the space. A dedicated outdoor air system (DOAS) is usually used to provide ventilation. As with other systems that decouple heating and cooling from ventilation, simultaneous heating and cooling can be drastically reduced or eliminated. Distribution energy is reduced, with water being a more efficient medium for transport of thermal energy. Radiant systems have the additional advantage of direct heat transfer with occupants—consequently, occupant comfort can be improved while also relaxing space temperature set points. These advantages can make radiant heating and cooling with DOAS among the lowest energy HVAC options. As the building delivery industry gains experience with these systems and exploits architectural integration options, they are becoming first-cost competitive with more traditional systems (Sastry and Rumsey 2014). The Program evaluated the performance of Gallagher Hall at UC Davis (Figure 6), which uses radiant heating and cooling with DOAS. See Section 4.3.2.3 and Attachment III for more information.

2.3.1.6 Ground Source Heat Pumps

Ground source heat pumps use the ground as the heat source/sink for refrigeration cycle heating and cooling—with relatively high efficiency because the ground is typically at a higher temperature than the air in the heating season and lower than the air in the cooling season. The ground acts as a buffer for daily, weather-driven, or seasonal heating and cooling cycles. Heat transfer with the ground can also be more efficient than heat transfer with ambient air. Performance depends on an annual balance between heating and cooling loads. Ground source heat pumps are not an energy source. The Program evaluated the energy performance of Gallagher Hall at UC Davis, which makes use of a ground source heat pump to meet part of its heating and cooling needs. See Section 4.3.2.3 and Attachment III for more information.

2.3.1.7 Indirect Evaporative Cooling

Indirect evaporative cooling can meet the entire cooling load of a commercial building in scenarios with a relatively mild climate and/or relatively low loads. It is most effective in dry summer climates. It can also be applied to cool data centers or other industrial facilities. Indirect evaporative pre-cooling can be employed to temper outdoor air supply, including dedicated outdoor air systems used in conjunction with chilled beam or radiant cooling systems. It can take the form of a cooling tower or "fluid cooler" producing chilled water, or an air-to-air heat exchanger (Figure 7). The Program evaluated the energy performance of Gallagher Hall at UC Davis, which uses indirect evaporative pre-cooling for the dedicated outdoor air system and indirect evaporative fluid cooling for the radiant cooling system. See Section 4.3.2.3 and Attachment III for case study information.

Figure 7: Evaporative Cooling System

2.3.2 Technologies with 2012–2014 Carryover Program Activity

2.3.2.1 Constant-Volume (CV) to Variable-Air-Volume (VAV) Conversions

Converting conventional packaged rooftop units or built-up constant-volume air handlers from constant volume to variable air volume saves fan energy. Various technologies and control techniques are available so the solution can be tailored to the specific application. Dramatic fan energy savings can be achieved by moving only as much air as is needed to satisfy ventilation and conditioning loads. Energy use for compressors, pumps, boilers, and furnaces can also be reduced by operating these systems at variable speed in association with the demand for conditioning. A variation of this technology was previously demonstrated in conjunction with the Federspiel Controls (now Vigilent) Discharge Air Regulation Technique (DART)[6], a wireless control technology (Johnson et al. 2011) (Figure 8). The technology was demonstrated without wireless

Figure 8: Federspiel Controls DART Devices

[6] Web-based, wireless, supervisory control system for commercial building HVAC systems.

technology as a part of a comprehensive HVAC retrofit at the Beale AFB Contrails Inn Dining Facility. See Section 4.3.2.5 and Attachment III for more information.

2.3.2.2 Demand Controlled Ventilation

Demand controlled ventilation manages the position of outside air dampers and flow rate of supply air to provide the right amount of ventilation to maintain indoor environmental quality without paying a penalty in energy use. ASHRAE 90.1 and Title 24 Building Energy Efficiency Standards have prescriptive requirements for the flow rate of fresh air in a space, but typical design strategies that provide continuous ventilation during business hours can use excessive fan energy and impose undue loads for conditioning. By monitoring the concentration of carbon dioxide (CO_2) in a space, demand-controlled ventilation can provide as much fresh air as is appropriate for actual occupancy levels (Figure 9). This technology was demonstrated as a part of a comprehensive HVAC retrofit at the Beale AFB Contrails Inn Dining Facility. See Section 4.3.2.5 and Attachment III for more information.

Figure 9: CO_2 Monitor

2.3.2.3 Premium Efficiency and Variable Speed Motors

Motors that were manufactured before the Energy Policy Act's minimum motor efficiency requirements took effect in 1997 can be 10 percent less efficient than contemporary premium efficiency models. When controlled by a variable frequency drive to operate at partial speed, the efficiency of these premium induction motors can slip by 20 percent (Figure 10). In applications where motors will operate over a wide range of torque and speed, and for systems that operate at partial speed for a significant amount of time, it can be worthwhile to install permanent magnet motors or electronically commutated motors (ECM). These systems maintain high efficiency at partial speed, and avoid the generation of electronic noise typical of induction motors with variable frequency drives. This technology was included in the comprehensive building retrofit demonstration at Beale AFB Contrails Inn Dining Facility. See Section 4.3.2.5 and Attachment III for more information.

Figure 10: Variable Speed Motor

2.3.2.4 Evaporative Condenser Air Pre-cooling

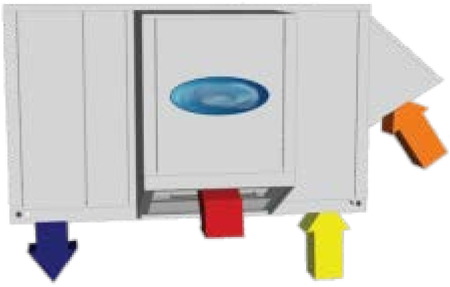
The energy efficiency of air-cooled vapor compression air conditioning is strongly dependent on the condenser air temperature; evaporative pre-cooling this air can save energy. Evaporative condenser air coolers are designed as retrofit add-ons to existing systems and can reduce energy consumption by conventional packaged rooftop air conditioners or air-cooled chillers by up to 20 percent in hot, dry climates (Figure 11). Like integrated evaporative condensers, these systems are designed to require minimal maintenance by using materials selected for continuous water contact, and by bleeding sump water to maintain a low concentration of solids. This technology was included in the comprehensive building retrofit demonstration at Beale AFB Contrails Inn Dining Facility. See Section 4.3.2.5 and Attachment III for more information.

Figure 11: Evaporative Condenser Air Cooler

2.3.2.5 Western Cooling Challenge Hybrid Packaged Rooftop Air Conditioners

Western Cooling Challenge (WCC)-certified equipment uses at least 40 percent less energy than conventional U.S. Department of Energy (DOE) 2010 standard vapor compression systems under typical hot-dry climate conditions encountered in western U.S. climates. The first certified equipment uses 65 percent less energy than comparable conventional systems at Western Cooling Challenge test conditions, while also providing significantly more outside air (Figure 12). Two demonstrations of early WCC technology were completed; one at the University House on the UC Davis campus, and the other at China Lake Naval Air Weapons Station (NAWS). More recent WCC product offerings are expected to be more prominent in the market. See the technical report in Attachment III for more information.

Figure 12: Hybrid Rooftop Air Conditioner



2.3.3 Technologies with Previous Program Activity

2.3.3.1 Wireless Controls for Building HVAC Systems

Wireless communications for sensor and control devices can allow more-efficient HVAC operation in applications where conventional wired solutions would be untenable. The advancement of these capabilities allows for (1) reliable communication between network nodes, such as temperature sensors or thermostats, and (2) communication with central control systems, where advanced algorithms can make more informed decisions about system control, and facility managers can have more insight into building operations than ever before. Wireless technology has been integrated into previous demonstrations of HVAC system retrofits such as the Federspiel Controls (now Vigilent) DART and Static Pressure Reset strategies (Johnson et al. 2011)[7].

2.3.3.2 Advanced VAV Design

Conventional VAV systems can use excess fan power and require excess energy for reheat because the control of supply air flow is not well balanced with the operation of the VAV terminal units. For example, in some older VAV systems, fan speed is adjusted based on the open-loop control signal for position of VAV dampers. In others, fan speed is controlled to maintain a fixed static pressure in the supply duct. Advanced VAV control strategies can use feedback from static pressure measurements and from VAV damper position sensors to vary fan speed and maintain critical conditions to achieve appropriate flow through each VAV terminal unit (Figure 13). The PIER Program produced the *Advanced VAV Design Guide* as a resource for these best practices (CEC 2005; Hydeman et al. 2003; Johnson et al. 2011)[8].

Figure 13: Advanced Variable Air Volume System

2.3.4 Other Technologies of Interest

2.3.4.1 Cool Roofing

Cool roofs use materials with high reflectivity to absorb less heat and stay dramatically cooler than conventional roofs under summer solar exposure (Figure 14). This reduces building cooling loads, increases the life expectancy of a roof, and reduces the urban heat island effect. As of 2005, cool roofs are a prescriptive requirement in Title 24 Building Energy Efficiency Standards. Technologies for low-sloped roofs are generally white, while materials for steep-sloped roofs may be various colors and configurations while still maintaining high reflectivity (Akbari and Miller 2006).

Figure 14: Cool Roofs

[7] See the SPEED website at partnershipdemonstrations.org for more information.

[8] See the SPEED website at partnershipdemonstrations.org for more information.

2.3.4.2 Advanced Economizer Controls

Conventional economizer controls are based on a single outdoor air temperature or enthalpy measurement and a fixed set point for changeover between economizer and standard cooling modes. For typical packaged rooftop air conditioners, economizer controls disable compressor cooling when in economizer mode, and the changeover to economizer mode only occurs when the outside air is cool enough to provide supply air to the space. More sophisticated economizer control schemes for rooftop units use temperature and enthalpy measurements for outdoor air and return air, then adjust the return air and outdoor air damper positions accordingly, and manage cycling of mechanical cooling so as to provide cooling as efficiently as possible (Figure 15). These economizer control schemes can be included in new rooftop systems or installed as retrofits in systems with existing economizers.

Figure 15: Advanced Economizer Controls

2.3.4.4 Combined Evaporative Cooling and Evaporative Condenser Air Cooling for Rooftop Package Units

This technology uses direct evaporative cooling to provide cool air to the condenser, and circulates water from the sump of this cooler through a water coil in the ventilation air stream to provide indirect evaporative cooling of the outside air; thereby reducing the cooling load for the vapor compression system (Figure 16). Energy savings for this system are twofold—it reduces the vapor compression cooling load and improves cooling efficiency. This technology can be installed as an add-on to a range of sizes and configurations of rooftop packaged air conditioners. It has the most impact on systems that provide dedicated outside air, or have a high ventilation rate. A demonstration was proposed with the U.S. Navy Southwest Region, but could not be implemented because of base security and access issues.

Figure 16: Combined Evaporative Cooling and Condenser Unit

2.4 Heating Ventilation, and Air Conditioning: Specialty Applications

The SPEED Program showcased PIER Industrial Agriculture and Water (IAW) Program technologies in 2007–2010, including the following:

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

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

Now generically referred to as Wireless Controls for Data Center HVAC Retrofits, the DASH technology was targeted for a pilot-scale deployment in 2010–2012 following the successful demonstration in 2009 (Brown et al. 2012). A few UC and CSU campuses have adopted a newer form of centralized demand controlled ventilation in the form of Aircuity technology.

The subsections below summarize these two IAW technologies. Two new specialty HVAC technologies are also featured:

- Demand Controlled Ventilation for Commercial Kitchens (ongoing activity)
- "Shut-the-sash" practices for Laboratory Fume Hoods (new)

2.4.1 Technologies with 2012–2014 Program Activity

2.4.1.1 Shut-the-Sash Practices for Fume Hoods

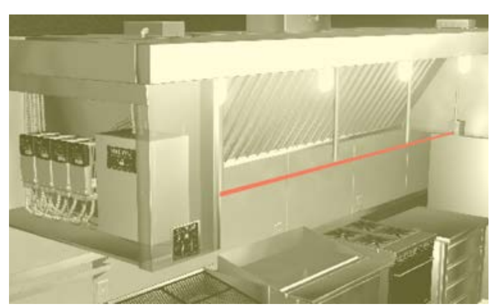
One of the simplest ways to reduce the energy required by operating fume hoods is to ensure that the sash—the moveable pane in front of the fume hood that controls the exhaust flow from an experiment—is always in the lowest possible operating position. This simple action can in some circumstances substantially lower the amount of energy used and will in all cases provide for the safest working environment. Behavioral change programs to promote being mindful of sash heights have been dubbed "shut-the-sash." In 2012–2014, shut-the-sash practices were explored in a collaborative project that included the WCEC, the Alliance to Save Energy (ASE) PowerSave Campus program, Lawrence Berkeley National Laboratory (LBNL), and two UC campuses. See Section 4.3.3.1 and the case study in Attachment II for more information.

2.4.2 Technologies with Carryover Program Activity

2.4.2.1 Demand Controlled Ventilation for Commercial Kitchens

Ventilation in commercial kitchens can account for half of the HVAC energy use in restaurants and dining facilities. Conventionally, kitchen exhaust fans and the associated makeup air handlers are switched manually and left to run at full speed for all operating hours. Demand control for these systems will automatically manage fan operation and speed to provide an appropriate degree of ventilation according to the temperature and effluent sensed in each kitchen hood. Demand-controlled kitchen ventilation often reduces fan energy by more than 50 percent, and will reduce conditioning loads for these spaces by 20 percent or more (Figure 17). This technology is now required in many scenarios by the 2013 update to Title 24. A business case and updated case study summary was completed for this technology built upon case studies in previous program phases. See Attachments

Figure 17: Demand Controlled Commercial Kitchen Ventilation System



II and IV for more information.

2.4.3 Technologies with Previous Program Activity

2.4.3.1 Intelligent Controls for Data Centers

Conditioning for data centers is often operated as an open-loop system, sized to overcome the thermal load of data systems under the worst-case scenario, and set to operate continuously without feedback about actual demand. Various best-practice strategies provide some improvements, but dynamic controls can decrease cooling energy use in data centers by as much as 50 percent. With the use of wireless mesh networking, the implementation of such a system can be very quick, and made to integrate seamlessly with an existing controls infrastructure (Figure 18). This technology was demonstrated as the Data Center Automation Hardware and Software (DASH) technology from Federspiel Controls (now Vigilent). The demonstration integrated variable speed fans, adjustable server fan inlets, and wireless temperature sensors to continuously adjust cool air volume 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 (Johnson et al. 2011; Brown et al. 2012)[9].

Figure 18: Data Center Using Advanced Cooling Controls

2.4.3.2 Centralized Demand Controlled Ventilation (for Laboratories)

Lawrence Berkeley National Laboratory originally investigated centralized demand-controlled ventilation as a part of its work on laboratory energy efficiency (Johnson et al. 2011). This technology can substantially reduce laboratory HVAC energy use by employing higher ventilation rates only when labs are occupied and/or 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). Aircuity has commercialized a version of this technology utilizing centralized monitoring of air samples. The University of California, Irvine, the host campus for the original investigation, has deployed the Aircuity technology in several laboratory buildings. A few other UC and CSU campuses have adopted the Aircuity technology, with increasing interest on additional campuses.

[9] See the SPEED website at partnershipdemonstrations.org for more information.

2.5 Building Energy Management

The Program explored the following building energy management technologies in 2004–2010:

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

Monitoring-based commissioning has now been deployed at scale, accounting for a large fraction of the achieved savings from demonstrated PIER technologies (see Section 6.2). The Program continues to observe deployments of monitoring-based commissioning, assisting the UC/CSU/IOU Partnership with best practices, and advising the IOUs and State of California Department of General Services on possible deployment in state facilities.

The Program worked with benchmarking and energy information systems during the original period of assistance to MBCx deployment in 2004–2010 by the UC/CSU/IOU Partnership. The University of California at Merced and LBNL continued to develop building performance visualization technology field tested in 2007–2010 in cooperation with the DOE.

The Program worked with UCOP in 2010–2014 to develop whole-building all-inclusive benchmark-based energy performance benchmarks for all UC campuses. This is based on energy planning and design targets developed for UC Merced by CIEE.

2.5.1 Technologies with 2012–2014 Program Activity

2.5.1.1 Whole-Building Benchmark-Based Energy Performance Targets

The California Institute for Energy and Environment originally developed whole-building benchmark-based energy performance targets for the new UC Merced campus (Brown 2002; Brown et al. 2010). Others have explored similar concepts (AEC 2009). The SPEED program then called on PIER-funded researchers at LBNL to apply benchmarking approaches to enhance the UC/CSU/IOU Partnership MBCx program element (Mills and Mathew 2009). The University of California at San Francisco subsequently asked CIEE to adapt the UC Merced benchmarks and targets for use on its multiple campuses. In 2012–2014, the Program supported University of California, Office of the President (UCOP) in adapting the benchmarks and targets for use by all 10 UC campuses.

Whole-building benchmark-based energy performance targets have several advantages over "beyond code" approaches to goals for energy efficient building design. All aspects of building energy use are addressed, not just those regulated by code. A static baseline provides a basis for tracking improvement in design over time. Validation of performance through measurement of actual use is possible. Please see Section 4.3.4.1 and Attachment III for more information.

2.5.2 Technologies with Carryover Program Activity

2.5.2.1 Monitoring-Based Commissioning

A team led by the Lawrence Berkeley National Laboratory explored the Information, Monitoring, and Diagnostic System (IMDS) technology in the 1990s, with initial funding by

CIEE for the pilot site at 160 Sansome Street in San Francisco (Piette et al. 2000). The PIER program 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 the UC/CSU/IOU Partnership using California Public Utilities Commission (CPUC)-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 pilot UC/CSU/IOU Partnership. This partnership was initiated in the 2004–2005 cycle of energy efficiency deployment funding administered by the CPUC.

The 2004–2005 UC/CSU/IOU Partnership MBCx Program was 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 UC/CSU/IOU Partnership, as described in Section 4.3.4.2.

The Program continued to support MBCx in UC/CSU/IOU Partnership activities in 2012–2014, including Best Practice awards in conjunction with the California Higher Education Sustainability Conferences.

CHAPTER 3: Program Partners

3.1 Core Demonstration Partners: UC and CSU Campuses

The Program's first three years (2004–2007) focused on demonstration sites within the UC and CSU systems. The two university systems, their campuses, and the UC/CSU/IOU Partnership provide a highly effective collaboration and venue for demonstration, scaled deployment, and feedback to R&D efforts. These partners greatly facilitated launching the Program and introducing an initial set of PIER technologies into an important market sector.

In the first three years, the Program also partnered with NYSERDA, the National Electrical Manufacturers Association (NEMA), and the Northwest Energy Efficiency Alliance (NEEA)—three groups similarly interested in development and demonstration of energy-efficient building technologies.

3.1.1 The UC/CSU/IOU Partnership

In 2004, UC, CSU, and California IOUs formed the statewide UC/CSU/IOU Partnership and received funding from the CPUC for a wide variety of projects to increase the efficiency of university facilities. The UC/CSU/IOU 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 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 with a focus on increasing energy efficiency. SPEED team members began to work directly with the campuses and with the UC/CSU/IOU Partnership to combine the mutual objectives and opportunities of the two programs. PIER has strongly supported all three elements of the UC/CSU/IOU Partnership.

All UC and CSU campuses are eligible to participate. Demonstrations and other technology transfer activities are intended to prove the merits and promote the adoption of new technologies on campuses throughout the UC and CSU systems. The Program helps to organize the installation of the technologies on campuses, and facilities managers receive training and support to maximize the technologies' benefits.

3.2 Other Demonstration Partners for 2007–2012

The Program explored collaboration with other partners over the next five years (2007–2012), including demonstration sites at California community colleges, California state agency facilities, local government agencies in California, California National Guard facilities, U.S. military facilities in California, and private-sector firms associated with the Silicon Valley Leadership Group (SVLG). These demonstration venues provided some important opportunities to showcase PIER technology and to connect with some additional market sectors. They required more coordination resources because of more widely distributed organizational structures.

From 2007–2012, the Program also explored collaboration with IOU programs in several important ways. This included:

- Collaboration with an emerging technology (ET) program in a demonstration,
- Savings-by-Design program's "Energy Design Resources" co-funding for the enhancements for version 4.0 of the daylighting Senior Placement + Optimization Tool (SPOT) in 2008 and 2009,
- Migration of PIER technologies into rebate programs, and
- Efforts by utility codes and standards support programs to include PIER technologies in enhancements of Title 24.

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 many 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. However, the initial success of these demonstrations did not create momentum within the CCC network comparable to the UC and CSU successes. Subsequent efforts to organize more demonstration projects were unsuccessful.

Demonstrations were organized at the Los Angeles Trade-Technical College when that campus became the site of the 2010 California Higher Education Sustainability (CHES) Conference. These demonstrations were not as successful as the demonstration clusters at the 2007–2009 and 2011–2013 CHES Conferences—which typically resulted in case studies, follow-on deployment of the technology at the host campus, as well an increase in interest in the technologies among conference attendees from other campuses. Please see Sections 4.3 and 5.1.2.1 for more information on CHES Conference activities in 2012–2014.

3.2.2 California State Agencies (Department of General Services)

The State of California is one of the largest building owners in the state. The Department of General Services (DGS) operates a broad range of structures for the State of California, from multi-story offices to garages and warehouses. In 2007–2010 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
- Department of General Services (Ziggurat Building)

3.2.3 Cities, Counties, and Special Districts (Local Government)

In 2007–2010 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 projects 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 the Sacramento Municipal Utility District (SMUD). The Program also developed a demonstration of bi-level LED parking garage fixtures with the City of San Marcos.

3.2.4 California National Guard

In 2007–2010 the Energy Commission project manager requested that the Program expand to include the California National Guard as potential hosts of Program demonstrations. The Program planned and organized a co-funded Integrated Office Lighting System (IOLS) at the National Guard headquarters in Sacramento. 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 smart exterior lighting and interior lighting technologies.

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 (Johnson et al. 2011).

3.2.6 Carryover Documentation in 2012–2014 with Beale Air Force Base

In 2010–2012, the Program organized and implemented demonstration of a comprehensive portfolio of retrofit measures for the Contrails Inn Dining Facility at Beale AFB, north of

Sacramento, California. The demonstration was intended to provide a template for best practice energy efficiency for U.S. Air Force facilities, particularly in food-service facilities.

This project was unique for the SPEED program in a number of ways. First, the demonstration venue was pre-designated, and a number of circumstances not conducive to a demonstration project had to be managed. Second, the scope of the project was an entire building, as opposed to a room or wing of a building. Third, the scope of the project was to include as many cost-effective measures as possible, including but not limited to PIER technology, and encompassing both lighting and HVAC systems. The basic cost for installation of the demonstration measures themselves was at least as large as a cluster of demonstrations typically installed at the host site of the CHES Conferences. Access issues for a secure military base further increased installation costs. Demonstration organizational, evaluation, and documentation costs were also increased by both base logistic issues and the multiple levels of approvals required. This demonstration project used in excess of 40 percent of the entire budget for 2010–2012 Program activities.

In 2012–2014, additional documentation was obtained for electric energy use at the Beale AFB Contrails Inn whole-building retrofit site. A follow-up report was created to document whole-building energy savings and further summarizes HVAC retrofits. A case study of the condenser air pre-cooling retrofit element was completed. See Section 4.3.1.5 and Attachments II and III for more information.

3.2.7 Carryover Documentation in 2012–2014 with United States Navy Southwest Region

In 2010–2012, the Program partnered with the U.S. Navy Southwest Region to specify PIER lighting technology in procurements associated with major retrofit efforts on U.S. Navy and U.S. Marine Corps bases. The Program also surveyed promising base sites for demonstration opportunities. A number of venues were identified for both PIER lighting and PIER HVAC technology demonstration projects.

One demonstration of a high performance package rooftop air-conditioning unit (Coolerado H80) was initiated at the China Lake Naval Air Weapons Station (NAWS). This demonstration was enabled by facility agreement to do all installation and monitoring in-house, with no need for Program procurement of demonstration fabricators or for Program personnel to work in hands-on scenarios on the base. The WCEC provided advice on all aspects of the installation and monitoring. However, no agreement could be reached on terms for base access for WCEC to perform hands-on work or procure installation of the demonstration. A technical report documenting Coolerado H80 performance at China Lake NAWS and UC Davis was completed in 2012–2014. See Section 4.3.2.6 and Attachment III for more information.

Other potential demonstrations were not initiated because the participants were not able to agree on terms for providing Program or installation personnel access to other bases. A base installation and monitoring scenario could not be negotiated for any sites except the China Lake facility. As an alternative to demonstrations, the Program also started to work with the Naval Facilities Engineering Command that facilitates the implementation of projects for the bases, as well as individual bases, providing information and recommendations for incorporating PIER technologies into their ongoing projects.

3.3 Other Organizations Supporting Technology Development and Demonstration

3.3.1 California Investor-Owned Utility Emerging Technology Programs

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

Program demonstrations and information dissemination activities are targeted to a higher-education facility and 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 often necessary for inclusion of technology in standard utility incentive programs.

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, an ongoing project initiated in 2009 and described in sections 4.3.1.3, 6.5.2.1 and Appendix V.

CHAPTER 4: Demonstrations

From 2012–2014, the Program built upon the 2004–2012 portfolio of more than 100 demonstration, field research, and technology transfer projects. To maximize demonstration opportunities and the depth of impact, the Program returned to an exclusive focus on UC and CSU campuses, as it had in the 2004–2007 time frame.

The UC/CSU/IOU Partnership remained the most effective path to scaled deployment of PIER technology, including substantial subsidies for retrofits and monitoring-based commissioning, along with the strong UC loan program to fund the balance of deployment projects, and strong policy goals for both systems. (Please see Chapter 3 for more information about demonstration host partners.)

In 2012–2014, the Program continued the more informal project selection process used in 2007–2012. Projects were developed with leads from PIER personnel, market sector representatives, and Program personnel. Projects were selected for the best opportunities to showcase newer technologies or to lead to pilot-scale deployment of PIER technologies. Several projects initiated from 2007–2012 were carried over for completion in the 2012–2014 phase of the Program. There was continued initiative for more cost sharing for 2012–2014 demonstrations. Please see Section 4.2 for a tabulation of all Program projects.

4.1 Demonstration Project Process

The typical demonstration project process began by matching technologies with a host site. Often, several candidate sites were considered before finding a suitable match. 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 was 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 (2007–2014).[10] The retrofit process included project commissioning, which sometimes extended to resolution of issues identified through the post-retrofit monitoring.

[10] In the early years of the Program (2004–2007), all demonstration installation costs were typically borne by the Program. This was appropriate to establish initially the value provided by the technical assistance, analysis, evaluation, and documentation provided by the Program. Full funding of demonstration installations was also commensurate with the full subsidy of projects in the pilot phase of the UC/CSU/IOU Partnership in 2004–2005. The early emphasis on lighting demonstrations, with relatively low materials and installation costs, made full funding economically feasible.

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 (e.g., 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.

4.1.1 Matching Technologies with Host Sites

As described earlier, the first program demonstration projects in 2004–2007 identified appropriate technologies through a solicitation process involving all UC and CSU campuses. Subsequent demonstration projects identified appropriate technologies through an iterative consultative process with Energy Commission managers, UC/CSU/IOU Partnership leaders, 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 from 2012-2014 remained key to the broader program success, 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 host organization’s level of engagement had to match the Program needs. In addition, the host organization’s technical capabilities and leadership potential needed to be appropriate for the stage of market adoption of the technology. The representative nature of the 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 (CHES) 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 often 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 and air quality for building or area occupants,
- Improved thermal comfort, 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 were relatively straightforward, and a two-week monitoring period was often 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 suite of HVAC technologies at the Beale AFB Contrails Inn Dining Facility. 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, and sometimes to estimate statewide savings in the event of large-scale technology implementation. Some monitoring equipment remained installed for a protracted length of time, in order 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 typically 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 Pre-retrofit 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, activities included the following:

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

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

4.1.3.2 One-time Tests

When possible, existing EMCS's 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.

4.1.3.3 Trending Data Acquisition Systems

Pre- and post-retrofit trend monitoring usually supplemented one-time measurements. When possible, existing EMCS's 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.

Occupancy data also contributed to a database of occupancy/vacancy information and the creation of a measurement and verification protocol for adaptive lighting retrofit projects. See Section 5.2.4.2 for more information.

4.1.3.5 HVAC-Specific Monitoring

For earlier projects (in 2004–2007), 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. Later projects (2007–2014) relied primarily on dataTaker data acquisition systems. These devices proved to be very flexible in their ability to handle a wide range of sensors and were highly programmable. Additionally, these units were equipped with cellular modem connectivity, allowing the data gathered during the day to be uploaded to a server nightly for analysis.

Updates also took place in the way power data was gathered. In earlier projects the primary device used for power monitoring was the WattNode™ brand power transducer. 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. The transducer sent pulses to the MDLs, which totaled and recorded them every five minutes. This technique enabled the team to measure the total power consumed over the interval, rather than an instantaneous measurement that could fluctuate more rapidly, causing errors in the power calculation. Later projects relied heavily on the Dent PowerScout3+ power-monitoring product. This product offered the advantage of including a Modbus interface allowing up to 128 power-monitoring devices to be interfaced to a single serial input on the data logger. This simplified field installations and allowed for increased power monitoring capabilities.

Monitoring for demonstration of low-energy personal comfort systems emphasized space temperature measurements and frequent surveys of occupants regarding thermal comfort. There was a focus on the range of space temperatures for which occupants reported satisfactory thermal comfort, as opposed to direct measurement of energy savings.

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 2007–2014 demonstrations, with the notable exception of the fully Program-funded comprehensive retrofit of the Beale AFB Contrails Inn Dining Facility.

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 often 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, coordination of installer trades, 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. 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 removing 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 was analyzed to develop the required performance metrics. These were compared to the pre-retrofit metrics to assess performance. 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.

Depending on the technology and demonstration specifics, possible deployment scenarios of retrofit, replacement, and/or new construction may have been emphasized. *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 generally 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 generally 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 often 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), technical reports (see Attachment III), and business cases (see Attachment IV), as well as in published papers, conference presentations and other documents (see Attachment V). 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.

Business cases were an addition to Program documentation for 2012–2014. Business cases focused on financing options available to UC and CSU campuses, supporting campus managers in the development of retrofit projects.

Since 2004 venues for articles and presentations have included the Illuminating Engineering Society publication *LD+A,* the Greenbuild conference, the American Council for an Energy-

Efficient Economy Summer Study on Energy Efficiency in Buildings, the California Higher Education Sustainability conference, West Coast Utility Lighting Team meetings, an Energy Policy Advisory Committee meeting, a Consortium for Energy Efficiency meeting, and the CLTC Retrofit Forums. Please see Chapter 5 for more information on 2012-2014 venues. The Program has created custom documentation utilizing demonstration results for the UC/CSU/IOU Partnership 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

Tables 4 through 10 summarize all demonstrations and special projects, along with a few of the scaled deployments initiated or facilitated by the SPEED Program.

Table 4: Demonstrations Interior Lighting (2004–2007)

	California State University (CSU)							University of California (UC)									Community Colleges			
	Northridge	San Diego	San Francisco	San Marcos	Sonoma	Stanislaus	2008 CHES Conference – San Luis Obispo	Office of the President – Oakland	Davis	Irvine	Los Angeles	Riverside	San Diego	San Francisco	Santa Barbara	2007 CHES Conference – Santa Barbara	Butte	Citrus	Cyprus	Southwestern
Smart (Bi-Level) Stairwell Lighting	X	X			P		X	X		X	X	X	X	X	X	X	X	X	X	
Integrated Classroom Lighting System (ICLS)			X	N P	P	X	X											X		X
Bathroom Smart Fixture and Switch					N		N		N											
Energy Efficient Downlights (CFL)				X					X							X				
Load Shed Ballast															X					
Open Digital Lighting Protocol									X											

CFL = compact fluorescent lamp, CHES = California Higher Education Sustainability, N = non-state (auxiliary) facility, P = Capital (New Construction or Renovation) Project

Table 5: Demonstrations Interior Lighting (2007–2014)

	California State University (CSU)		University of California (UC)						Community Colleges			State Agencies			Special Sites		
	2008 CHES Conference – San Luis Obispo	2011 CHES Conference – Long Beach	Office of the President – Oakland	Davis	San Francisco	2007 CHES Conference – Santa Barbara	2009 CHES Conference – Santa Barbara	2013 CHES Conference – Santa Barbara	Citrus	Cyprus	Southwestern	California Energy Commission	California DGS Ziggurat (with PG&E)	CDPH Richmond	Parks	CA National Guard Sacramento HQ	Beale Air Force Base Contrails Inn Dining Facility
Integrated Office Lighting System (IOLS)	X		X	X		X	X		X	X	X	X	X			C	
Smart (Bi-Level) Stairwell Lighting							X										
Integrated Classroom Lighting System (ICLS)		X													X		
Energy Efficient Downlights (LED)							N							X	X		X
Wireless Lighting Controls							X					X					
Wireless Lighting Controls (WIPAM)				C													
Simplified Daylighting Control							X										
Adaptive (Smart Bi-Level) Corridor Lighting		X		X													
Adaptive Corridor Lighting (Next Generation)					X			N									
Adaptive Office Lighting								N									

C = carryover, CA = California, CDPH = California Department of Public Health, CHES = California Higher Education Sustainability, DGS = Department of General Services, LED = light-emitting diode, N = non-state (auxiliary) facility, PG&E = Pacific Gas and Electric Company, WIPAM = Wireless Integrated Photosensor and Motion Sensor System, [green] = 2010–2012 project, [cyan] = 2012–2014 project

Table 6: Demonstrations Exterior and Garage Lighting

	California State University (CSU)							University of California (UC)						Community Colleges	State Agencies	Special Sites		
	Chico	Pomona	East Bay	Sacramento	San Francisco	2008 CHES Conference – San Luis Obispo	2011 CHES Conference – Long Beach	Irvine	San Francisco	2007 CHES Conference – Santa Barbara	2009 CHEC Conference – Santa Barbara	2012 CHES Conference – Davis	2013 CHES Conference – Santa Barbara	2010 Conference - LA Trade & Technical	CDPH Richmond	Sacramento Parks	City of San Marcos	Beale Air Force Base Dining Facility
Low Glare Outdoor Luminaire		X								X								
Smart (Bi-Level) Wall Pack Lighting	X									X	X							X
Smart (Bi-Level) Wall Pack Lighting (WIPAM)							X											
Smart (Bi-Level) Pathway Bollards						N	X								X	X		
Smart (Bi-Level) Garage Luminaires (Fluorescent)											X							
Smart (Bi-Level) Garage Luminaires (Induction)								U			X							
Smart (Bi-Level) Garage Luminaires (LED)				X							X						C	
Smart (Bi-Level) Parking Luminaires (Induction)					X	X	X				X			C	X			
Smart (Bi-Level) Parking Luminaires (LED)			X			X	X		X		X			C				X
Networked Wall Pack Lighting (LED)												X						
Networked Site Lighting												X						
Networked Post Top/Collar Path Luminaires (LED)													X					
Adaptive Site Lighting													X					

C = carryover project, CDPH = California Department of Public Health, CHES = California Higher Education Sustainability, LA = Los Angeles, LED = light-emitting diode, U = Retrofit Upgrade, WIPAM = Wireless Photosensor and Motion Sensor System, [green] = 2010–2012 project, [cyan] = 2012–2014 project

Table 7: General Applications HVAC and Energy Management Technology Demonstrations 2004-2010

	California State University (CSU)			University of California (UC)						
	East Bay	Stanislaus	2008 CHES Conference- San Luis Obispo	Office of the President - Oakland	Berkeley	Los Angeles	Merced	San Diego	Santa Barbara	2007 CHES Conference – Santa Barbara
Wireless Retrofits: Static Pressure Reset, DART VAV Conversion		X	X	X	X					X
HVAC Diagnostics	X		X			X		X		
Air Flow Measurement and Control (IAQ-62)		X							X	
Field Research: Occupancy-Based Control							X			
Field Research: Chiller Optimization							X			
Alpha Test: Performance Visualization							X			

CHES = California Higher Education Sustainability, DART = Discharge Air Regulation Technique, HVAC = heating, ventilation, and air conditioning, IAQ = indoor air quality, VAV = variable air volume

Table 8: General Applications HVAC and Energy Management Technology Demonstrations 2010–2014

	California State University (CSU)		University of California (UC)		Special Sites	
	Long Beach	2014 CHES Conference – San Diego	Davis	Berkeley	U.S. Navy China Lake Weapons Station	Beale Air Force Base Dining Facility
Large System Duct Sealing			X X			C
High Performance Rooftop Package HVAC			C		C	
Occupancy Sensing Networked Thermostats			C			
Constant Volume to VAV Conversion						C
Condenser Air Pre-Cooling						C
Demand Controlled Ventilation						C
Premium Efficiency and Variable Speed Motors						C
Advanced Retrofits for Rooftop Package Units	X	N				
New Construction Case Study			C			
Personal Comfort Systems				C		

C = carryover project, CHES = California Higher Education Sustainability, HVAC = heating, ventilation, and air conditioning, N = non-state (auxiliary) facility, VAV = variable air volume, [green] = 2010–2012 project, [cyan] 2012–2014 project

Table 9: Specialty Applications HVAC Demonstrations

	California State University (CSU)	University of California (UC)				Community Colleges	State Agencies	Special Sites		
	2008 CHES Conference – San Luis Obispo	Berkeley	Irvine	Los Angeles	2007 CHES Conference – Santa Barbara	Butte	CA Franchise Tax Board – Sacramento	Intel Corporation	Sun Microsystems	Beale Air Force Base Dining Facility
Commercial Kitchen Hood Demand Controlled Ventilation	X	X		X	X	X				C
Wireless Data Center HVAC Retrofits: Data Center Automation Software and Hardware (DASH)							X			
Alpha Test: IT Sensors for Data Center HVAC Control								X		
Alpha Test: Liquid Cooled Servers									X	
Beta Test: Centralized Demand Controlled Ventilation (Labs)			X							
Shut-the-Sash Programs for Lab Fume Hoods		X		X						

CA = California, CHES = California Higher Education Sustainability, HVAC = heating, ventilation, and air conditioning, [green] = 2010–2012 project, [cyan] = 2012–2014 project

Table 10: Assistance with Scaled Deployment

	University of California (UC) /California State University (CSU)	University of California			Special Sites
	Investor-Owner Utility (IOU) Energy Efficiency Partnership	Systemwide	Davis	Santa Barbara	U.S. Navy Southwest Region
Monitoring-Based Commissioning (MBCx), including Energy Information Systems	O				
Whole Building Benchmark-Based Building Energy Performance Targets		O			
Multiple Technologies: Training and Education	X				
Demand-Controlled Kitchen Ventilation Business Case	X				
Smart (Bi-Level) Stairwell Lighting Fixture: Group Purchase	X				
Smart Lighting			X		
Smart (Bi-Level) Parking/Area Lighting Fixtures					X
Smart (Bi-Level) Wall Pack Exterior Lighting Fixture					X
Adaptive Corridor Lighting Business Case	X				
Site Lighting Business Case	X				
Zero Net Energy Building Retrofit				O	

O = ongoing, X = 2010–2012 project, X = 2012–2014 project

4.3 Details of Demonstrations

4.3.1 Lighting

In 2012–2014, the Program, in partnership with UC campuses as host sites, continued to organize the installation of energy-efficient lighting system demonstrations. In some cases, these demonstrations illustrated innovative applications of new technologies. In others, they provided additional groundwork to build cases for retrofit or new construction projects using the technologies. Reports on some of these demonstration projects may be found in Attachment III—Technical Reports. Several of these projects resulted in PIER Demonstration case studies, which may be found in Attachment II. Some technologies were selected for business cases, which may be found in attachment IV. Please see Tables 1, 2, 3, and 7 for a summary of all SPEED program lighting demonstrations, including those from 2012–2014.

4.3.1.1 UC Davis (2012 California Higher Education Sustainability Conference)

At UC Davis the Program demonstrated 100 networked LED wall pack fixtures as a part of assistance with a campus-wide 1,500 networked LED exterior lighting fixture retrofit that also included post-top, area, and street lighting. This project was showcased at the 2012 California CHES conference. Case studies for both the wall pack demonstration and the campus-wide retrofit can be found in Attachment II.

4.3.1.2 UC Santa Barbara (2013 Higher Education Sustainability Conference)

At UC Santa Barbara adaptive LED office and corridor lighting was demonstrated and showcased at the 2013 CHES conference. This deep efficiency retrofit with 89 percent energy savings will help inform future lighting retrofits in Student Affairs buildings. Please see Attachment III for more information.

Also in conjunction with the 2013 CHES conference, the Program demonstrated LED street and pathway lighting including post-top and collar retrofits with adaptive and wireless options. Energy savings of 78 to 88 percent were achieved. Please see Attachment II for a case study of this demonstration.

4.3.1.3 UC Santa Barbara Recreation Center Zero Net Energy Retrofit

Multiple lighting technologies including network controlled gymnasium (high bay) LED lighting were installed as a part of the lighting phase of the zero net energy retrofit of the Recreation Center. This project with 75 percent energy savings may lead to comprehensive lighting retrofits in multiple Student Affairs buildings. See Attachment V for more information.

4.3.1.4 UC San Francisco

The Program demonstrated multiple adaptive corridor lighting technologies at UCSF with energy savings of 54 to 68 percent. This is a precursor to major adaptive corridor lighting retrofit projects planned in conjunction with the UC/CSU/IOU Partnership. Please see the case study and technical report in Attachments II and III for more details.

4.3.1.5 Beale Air Force Base Contrails Inn Dining Facility: Follow-on Documentation of Retrofit Energy Savings

In 2010–2012 the Program demonstrated a combination of interior and exterior lighting technologies at the Contrails Dining Facility (Arani 2012; Tatro et al. 2011). Interior retrofits consisted of volumetric recessed fluorescent luminaires, bi-level ceiling and wall-mounted fluorescent luminaires, and LED downlights. Exterior retrofits consisted of bi-level LED wall packs and bi-level LED parking lot luminaires. Additional electricity use information was collected in 2012–2014, allowing follow-up documentation on this whole-building retrofit. Please see the Technical Report in Attachment III.

4.3.1.6 Follow-on Business Case Development for Adaptive Corridor Options

The Program demonstrated adaptive corridor lighting at multiple sites in 2010–2014. Information from these demonstrations was compiled into a business case document intended to enable facility managers to make informed decisions about adaptive corridor retrofit projects. See Attachment IV for this and other Program business cases incorporating energy cost savings information with financing scenarios.

4.3.1.7 Follow-on Business Case Development for Exterior Site Lighting

The Program demonstrated multiple applications of adaptive exterior site lighting at multiple sites over the course of the Program. Information from these demonstrations was compiled into a business case document intended to enable facility managers to make informed decisions about adaptive corridor retrofit projects. Please see more information in Attachment IV.

4.3.2 Heating, Ventilation, and Air Conditioning: General Applications

In 2012–2014, the Program, in partnership with UC and CSU campuses as host sites, continued to organize the installation of energy-efficient HVAC technology demonstrations. Reports on some of these demonstration projects may be found in Attachment III. Some of these projects resulted in PIER Demonstration case studies, which may be found in Attachment II. See Tables 4 and 5 for a summary matrix of Heating Ventilation and Air Conditioning (General Application) demonstrations and other projects conducted by the Program.

4.3.2.1 UC Davis Art Building Aerosol Duct Sealing

The Western Cooling Efficiency Center evaluated the implementation of aerosol duct sealing in the Art Building at UC Davis. Please see the technical report in Attachment III for more information.

4.3.2.2 UC Davis Housing: Field Study for Networked Occupancy Sensing Thermostats

In collaboration with UC Davis Student Housing, WCEC continued to evaluate networked occupancy-sensing thermostat technology in several dormitory facilities at UC Davis. Please see the technical report in Attachment III for details.

4.3.2.3 UC Davis Gallagher Hall: Radiant Heating and Cooling, Ground Source Heat Pump, Indirect Evaporative Cooling

The WCEC worked with UC Davis Design and Construction Management to review their experience in designing, constructing, and commissioning the LEED™ Platinum Gallagher Hall. The building is a rare example of several unique design features that are generally espoused to be among the most energy-efficient strategies for heating, cooling, and ventilation. These include radiant heating and cooling with a dedicated demand-controlled outside air system, a ground-source heat pump, and indirect evaporative cooling used both for pre-cooling of outside air and in the radiant cooling system. Since occupancy, the building design and facility management team have run up against issues with the mechanical systems in the building, but are working through solutions to overcome the challenges. The SPEED program worked with the UC Davis team to monitor and evaluate energy performance in the building and to develop a case study focused especially on the lessons learned through this pioneering building design. Please see the technical report in Attachment III.

4.3.2.4 UC Davis and U.S. Navy Southwest Region, Naval Air Weapons Station at China Lake: Follow-on Documentation for Demonstration of Hybrid Rooftop Packaged Air Conditioning (Coolerado H80)

The Western Cooling Challenge invites HVAC manufacturers to develop the next generation of rooftop packaged air conditioning equipment that achieve at least 40 percent energy savings and demand reduction at full capacity operation compared to DOE 2010 standards. Coolerado was the first manufacturer to achieve WCC certification through laboratory testing and as part of the SPEED program, WCEC worked with UC Davis to install a pilot demonstration of the H80 hybrid rooftop unit. The U.S. Navy Southwest Region, Naval Air Weapons Station at China Lake served as another host site for an H80 demonstration.

The demonstrated technology has not progressed to market. Other manufacturer's products have gained certification and are more likely to capture significant market share. However, the demonstration yielded valuable performance information for this technology class in two distinct climates, as well as providing lessons learned regarding installation, commissioning, and field testing. Please see the technical report in Attachment III for more information.

4.3.2.5 Beale Air Force Base Contrails Inn Dining Facility: Follow-on Documentation of Retrofit Energy Savings

In 2011–2012 the Program implemented a comprehensive retrofit of HVAC and refrigeration systems for the Contrails Inn Dining Facility at Beale Air Force Base. Multiple HVAC technologies were employed, including both PIER-developed technologies and technologies included as a part of an integrated package of retrofits. A package of retrofit lighting technologies was also implemented (Arani 2012). The installation of the HVAC technologies was completed at the end of 2011, with evaluation to be performed and documentation completed in 2012 along with compilation of electricity use information for the demonstration. Overall energy savings were substantial, but tempered by some increased energy services provided by the retrofit systems. Please see the summary report in Attachment III for more information, including additional description of the following demonstrated technologies:

Condenser Air Pre-Cooling for a 40-ton Chiller

As part of the suite of efficiency retrofits conducted at the Contrails Inn Dining Facility, WCEC installed an Evaporcool™ condenser air pre-cooler for the building's 40-ton air-cooled chiller. Installation was completed in October 2011, with field evaluation of performance for the demonstration occurring during the 2012 cooling season. A separate case study was developed for this component of the demonstration and can be found in Attachment II.

Aerosol Duct Sealing

The SPEED program demonstrated the installation of Aeroseal in the supply and return ductwork for two air handlers at the Contrails Inn Dining Facility. The ductwork for each air handler was measured to leak by approximately 30 percent, and energy savings from sealing leaks is estimated to amount to more than 110,000 kilowatt-hours (kWh) annually, with a simple payback of less than six years at a $0.07 per kWh electric rate.

Demand-Controlled Kitchen Ventilation

The centerpiece of the HVAC retrofits conducted at the Contrails Inn Dining Facility was a demand-controlled kitchen ventilation system that provided variable speed operation for five rooftop kitchen exhaust fans, and one air handler, serving seven kitchen exhaust hoods. The measure was estimated to have a 4.2-year simple payback, based on the reduced fan energy and conditioning requirements.

Constant Volume to Variable Speed Conversion and Demand Controlled Ventilation

The single largest air handler at the Contrails Inn Dining Facility was retrofitted to operate at variable speed, with demand-controlled ventilation. Since the space is generally occupied in significant waves during each meal period throughout the day, the demand-controlled ventilation system was intended to reduce ventilation-conditioning load significantly. Separate evaluation of this measure was not possible.

High Efficiency Motor Replacements for Walk-in Refrigerator Evaporator Fans

In response to recommendations by the Food Service Technology Center, the SPEED program replaced all shaded pole evaporator fan motors in the Contrails Inn Dining Facility's walk-in refrigerators with permanent, magnet-type motors. While these motors have the ability to operate at part speed, they were installed in a constant-speed application, which was anticipated to reduce electrical demand by approximately 40 percent. Separate evaluation of this measure was not possible.

4.3.2.6 San Diego State University and California State University, Long Beach: Advanced Retrofits for Rooftop Package Units

Retrofits of rooftop package units are gaining popularity, with vendors providing packages containing ventilation fan speed control and other energy-saving features. The Transformative Wave Catalyst product is one such product gaining a long track record. The WCEC organized demonstrations of this technology at California State University Long Beach and San Diego State University. The latter demonstration was in conjunction with the 2014 California Higher Education Sustainability Conference. Energy performance was similar to that observed in other demonstrations. Valuable commissioning and field-testing experience was gained. Please see the case study in Attachment II.

4.3.2.7 University of California, Berkeley: Low-Energy Personal Comfort Systems

In 2012–2014, the Program supported the first field demonstrations of low-energy personal comfort systems (PCS) developed by the Center for the Built Environment (CBE) at UC Berkeley. The Center demonstrated the footwarmer PCS in the DOE Library Annex (Bancroft Library) at UC Berkeley in the winter of 2012–2013. Offices in the Cesar Chavez Student Union at UC Berkeley were the venue for demonstration of the chair PCS in the summer of 2013 and winter of 2013–2014, as well as for personal fans in the summer of 2013. Please see the case study in Attachment II and the technical reports in Attachment III for more information.

4.3.3 Heating, Ventilation, and Air Conditioning: Specialty Applications

The SPEED Program began demonstrating Demand Controlled Ventilation for Commercial Kitchens in 2004–2012. There is ongoing demonstration and business case development activity for this technology. Also in 2012–2014, the Program did a case study for Shut-the-Sash programs for laboratory fume hoods. A summary of all HVAC Specialty Application demonstrations can be found in Table 6, including technologies from activity with the IAW Program in 2007–2010.

4.3.3.1 UCLA and UC Berkeley: Shut-the-Sash Program for Laboratory Fume Hoods

Working with the Lawrence Berkeley National Laboratory and the Alliance to Save Energy, the WCEC helped organize pilot "shut-the-sash" programs at UC Berkeley and UCLA. Please see the case study in Attachment II for more information.

4.3.3.2 Follow-on Business Case Development for Demand Controlled Ventilation for Commercial Kitchens

Please see Section 4.3.2.5 for information about the demonstration of Demand Controlled Ventilation for Commercial Kitchens as a part of the comprehensive retrofit of the Beale AFB Contrails Inn Dining Facility. In 2012–2014, the Program updated case study information for this technology and developed a business case to help facility managers make decisions about retrofit projects. Please see the case study in Attachment II and the business case in Attachment IV for more information.

4.3.4 Building Energy Management

4.3.4.1 UC Systemwide Outreach for Whole-Building Benchmark-Based Energy Performance Targets

The California Institute for Energy and Environment had previously developed whole-building benchmark-based energy performance targets for the development of the new UC campus at Merced (Brown 2002; Brown et al. 2010). The system of benchmarks and targets was subsequently applied to a new building project at UC San Francisco. In 2012–2014, the UC Office of the President expressed interest in the benchmarks and targets, leading to the development of benchmarks and targets for all 10 campuses in the UC system. In December 2013 and January 2014, workshops were held at UC Irvine and UC Merced, respectively, to disseminate information to campus staff. A users group has since formed with periodic conference calls to share experiences using the benchmarks and targets. Please see the technical report in Attachment III for more information.

4.3.4.2 Documentation of Energy Savings for Monitoring-Based Commissioning Deployment with the UC/CSU/IOU Partnership

The SPEED Program assisted with a pilot deployment of Monitoring-Based Commissioning (MBCx) in conjunction with the 2004–2005 (pilot) UC/CSU/IOU Partnership. The Program provided technical support to the UC/CSU/IOU Partnership in the form of two LBNL documents:

- *UC/CSU/IOU Monitoring-Based Commissioning Program: Case Studies and Needs Assessment* (Haves et al. 2005)
- *Monitoring-Based Commissioning (Energy Information System) Architectures* (Haves and Watson 2005)

The Program continued to support the scaled deployment of MBCx in subsequent UC/CSU/IOU Partnership cycles from 2006–2014. This included a benchmarking analysis and report on the first 24 MBCx projects from the 2004–2005 UC/CSU/IOU Partnership cycle (Mills and Mathew 2009), as well as an updated survey of *Building Energy Information Systems: State of the Technology and User Case Studies* (Granderson et al. 2009).

The scaled deployment of MBCx continues to be a success, with the UC/CSU/IOU Partnership accumulating 44 million kWh per year and 3.6 million therms per year of energy savings through mid-2014 (see Section 6.2). Third-party programs adopted the MBCx approach in 2010–2012 with less success (see Section 6.2). Please see Attachment V for more information.

CHAPTER 5: Outreach

The outreach and education components of the 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 outreach efforts, which benefits the public interest 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 manufacturer. In the SPEED process, the products can be 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 Program evaluation, rather than relying solely on manufacturer literature. These audiences include the facility managers that host the demonstrations and the larger facility management community.

5.1 Outreach Venues

5.1.1 UC/CSU/IOU Partnership

The UC/CSU/IOU Partnership and its participating campuses are considered a SPEED Program partner because of the parallel evolution of the two programs and the many demonstrations that have led to scaled deployments of PIER technology through the UC/CSU/IOU Partnership (Please See Section 3.1.1 and Section 6.2). The UC/CSU/IOU Partnership has also been a major venue for outreach utilizing the Program's education and training tools.

Training and Education activities of the UC/CSU/IOU Partnership continued at a reduced level in 2006–2014.[11] The UC/CSU/IOU Partnership continued to fund the Best Practice Awards in conjunction with the CHES Conference. Projects utilizing PIER Technologies won some of these awards (see Section 6.8.2).

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[11] The UC/CSU/IOU Partnership had a substantial training and education element in its pilot 2004–2005 phase (Higgins 2007). The SPEED Program funded substantial technical assistance to this element, 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 UC/CSU/IOU Partnership. The course offerings were targeted primarily at university capital project management personnel, with architect and engineering consultants working on university capital projects and university facility management personnel also among the attendees.

The UC/CSU/IOU 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 (Johnson et al. 2011).

5.1.2 Conferences and Forums

The Program initiated, co-developed, or provided major contributions to forums and conferences showcasing new technology for higher education facilities, including the annual CHES Conference in 2012, 2013, and 2014. Program staff regularly participates in other major technology transfer venues such as the American Council for an Energy-Efficient Economy (ACEEE) Summer Study and the Utility Energy Forum. Key presentations and papers can be found in Attachment V.

5.1.2.1 California Higher Education Sustainability Conferences

The Program participates in the CHES Conference each year, through on-campus technology demonstrations, tours of the demonstrations, an exhibit booth, and presentations. The conference attracts over 700 participants, including many UC and CSU facilities staff. Materials associated with the conferences can be found in Attachment V.

The conference was held at UC Davis in 2012, UC Santa Barbara in 2013, and San Diego State University in 2014. Program staff also participated in the UC or UC/CSU Energy Managers meeting held in conjunction with each of these CHES conferences, participating on panels discussing topics that included monitoring-based commissioning or updates to Title 24 Energy Efficiency Standards.

5.1.2.2 ACEEE Summer Study

The Program presented a paper on its model for technology transfer and accelerating market adoption at the 2012 ACEEE Summer Study on Energy Efficiency in Buildings. That year the Program also presented a paper updating progress with monitoring-based commissioning. The papers can be found in Attachment V.

At the 2014 ACEEE Summer Study SPEED participation included a paper on the lighting part of the zero net energy retrofit of the UC Santa Barbara Recreation Center. See Attachment V for more information.

5.1.2.3 Other Conference and Forums

Utility Energy Forum

Program staff gave presentations on the SPEED Program at the 2012 and 2013 Utility Energy Forums. The attendees include multiple municipal utilities. The presentation can be found in Attachment V.

LIGHTFAIR International

Program team member CLTC attended LIGHTFAIR International 2012, 2013, and 2014—showcasing SPEED Program technology transfer materials.

West Coast Utility Lighting Group

The West Coast Utility Lighting Group (WCULG) was initiated by the Energy Commission and the SPEED Program, and has been meeting three to four times a year for the last five years. The group consists of PG&E, SCE, San Diego Gas & Electric, and SMUD, BC Hydro, Bonneville

Power Administration, Seattle City Light, CIEE, CLTC, and others. This forum has been important for coordinating and leveraging the SPEED and IOU demonstrations, field data, and program information for emerging lighting technologies.

5.1.3 Websites

Websites allow SPEED to post program documents for access by target audiences from the various market sectors. There are now three websites containing substantial Program content:

- State Partnership for Energy Efficient Demonstrations (SPEED)
- California Lighting Technology Center (CLTC)
- Western Cooling Efficiency Center (WCEC)

5.1.3.1 SPEED

The SPEED website[12] is dedicated to and focused on content directly produced by the Program. The site has a resource solutions library, a summary compilation of demonstrations and other Program projects, and a section summarizing Program impacts and results. Case studies, construction specifications, and other information can be accessed through the document library. The SPEED website is linked to CIEE's website[13].

5.1.3.2 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 Publications section of its website[14], alongside other Center lighting demonstration activities.

5.1.3.3 WCEC

The WCEC at UC Davis is another primary team member for SPEED. The WCEC posts Program documents on its website[15].

5.2 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 tools and materials help increase market penetration for PIER technologies and enhance benefits for early adopters.

5.2.1 Business Cases

In 2012–2014, the Program introduced business cases for select SPEED technologies, to provide additional information for development of projects using Program technologies. The business cases emphasize funding scenarios available in conjunction with the UC/CSU/IOU Partnership.

[12] partnershipdemonstrations.org

[13] uc-ciee.org

[14] cltc.ucdavis.edu/publications

[15] http://wcec.ucdavis.edu/resources/literature-and-publications/

Please see Attachment IV for business cases for the following technologies:

- Adaptive Corridor Lighting
- Pathway and Roadway Lighting
- Commercial Kitchen Hood Demand-Controlled Ventilation

5.2.2 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 case studies present an accessible, easily understood story about a select product or product category. Technology vendors often use the case studies to share success stories with interested buyers who are looking for a more objective opinion of new technologies. Manufacturers appreciate this valuable "third-party" perspective.

Case studies created or updated in 2012–2014 may be found in Attachment II:

New or updated lighting case studies in that attachment include:

- Networked Wall Pack Exterior Lighting at UC Davis (new)
- Networked Site Lighting at UC Davis (new)
- Adaptive Exterior Lighting at UC Santa Barbara (new)
- Adaptive LED Parking Lighting at UC San Francisco (new)

New or updated heating, ventilation, and air-conditioning case studies include:

- Commercial Kitchen Demand-Controlled Ventilation (updated)
- Evaporative Condenser Pre-cooling at Beale AFB (new)
- Evaluation and Benchmarking of Gallagher Hall at UC Davis (new)
- Advanced RTU Retrofits at CSU Long Beach and San Diego State (new)

5.2.3 Deployment Program Support

The Program produces custom analyses and technical documentation for support of major deployment subsidy programs or organizations seeking to participate in deployment programs. This can include "working paper" information about performance of technologies, best practices information, or analyses tailored to a particular program or large project.

5.2.3.1 Changes in Savings Accounting Baselines with 2013 Title 24 Update

The California Title 24 Energy Efficiency Standards serve as a baseline for savings accounting for retrofit projects incentivized by California investor-owned utilities, including UC/CSU/IOU Partnership incentives. The 2013 update to the California Title 24 Energy Efficiency Standards was accompanied by increased use of the standards as baselines for more retrofit projects, as well as the advent of stricter protocols regarding application of baselines. The aggregate result is more limited eligibility of some common types of retrofit projects along with more stringent baselines and accompanying decreases in incentives for many of the technologies retaining eligibility. The new standard became effective on July 1, 2014.

The UC/CSU/IOU Partnership utilities established deadlines for project applications that would be processed using the previous version of Title 24 as the baseline. Substantial Program activities were oriented around informing UC and CSU campuses about the impacts of the reduction in incentives on project economics, as well as the utility deadlines.

The business case for Demand-Controlled Kitchen Ventilation was expedited as that technology became a requirement of 2013 Title 24, and remaining eligible projects became limited to those for which the existing installation was within the effective useful life of the system. The business case for adaptive corridors included information about incentive levels with pre- and post-2013 Title 24 baselines. These business cases can be found in Attachment IV.

The Program also produced a special document—"SPEED Technologies: A Smart Investment, Critical Deadline Approaching"—highlighting the differences in available incentive levels pre- and post-2013 Title 24. This document can be found in Attachment V.

5.2.3.2 Documenting Occupancy Rates for Lighting Control Projects

The Program has historically monitored adaptive lighting technologies to determine the actual energy savings associated with lighting demonstration projects. As a result, the Program has been able to determine average occupancy levels based on how often bi-level luminaires switch from high to low mode for adaptive light output.

In 2012—2014, the Program and CLTC have continued to accumulate this information and can provide typical occupancy rates for specific lighting applications to end users interested in adaptive lighting technology retrofits. Observed occupancy rates are almost always lower than the default values typically applied to projects that do not directly measure occupancy for savings accounting. For a limited period, utility project reviewers would accept typical values compiled by the Program for higher education facilities in lieu of the default values from the DEER database. This is no longer the case. Occupancy rates lower than the DEER database values must now be verified on a project-by-project basis, so the value of the Program-developed information has shifted to developing occupancy/vacancy monitoring and verification (M&V) plans for new technologies.

The SPEED program and UC Santa Barbara (UCSB) developed a corridor occupancy/vacancy M&V study with SCE for use with a UC/CSU/IOU Partnership incentive-supported bi-level corridor retrofit project application and savings validation. The study monitored 50 corridors in 11 buildings and documented an average occupancy of 11 percent. The 11 percent occupancy will be used for the energy savings and the incentive estimates versus the standard Database for Energy Efficient Resources (DEER) assumption of 86 percent occupancy. This may set a precedent for this M&V plan to be used for other campus applications.

The Program also continues to add project findings to the database in anticipation of an opportunity to demonstrate in a broader context the lower occupancy rates and higher value from adaptive lighting retrofit projects.

5.2.4 Tools and Materials from 2004–2012

5.2.4.1 PIER Lighting Technology Catalogs

Pubic Interest Energy Research program-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.

These state-of-the-shelves circa 2012 energy-efficient luminaires are presented in two CLTC catalogs: (1) PIER Solutions for Classrooms and Conference Rooms, and (2) PIER Solutions for Parking Lots and Garages. 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. The catalogs were used at trade shows and other special lighting events, and are available for download from CLTC's website.

The Program produced special web-based versions of these catalogs on the SPEED website:

http://pierpartnershipdemonstrations.org/solutions/parking-lots-garages

http://pierpartnershipdemonstrations.org/solutions/class/conference-rooms

5.2.4.2 Video Case Studies

The Program has produced video case studies, including virtual tours of demonstrations conducted at UC Davis, extending the impact of these leading-edge initiatives by the CLTC host campus. In 2010–2012, the Program released a video case study of the Wireless Integrated Photosensor and Motion Sensor (WIPAM) system, to accompany the previously released video case study of the UC Davis Exterior Lighting Retrofit[16].

5.2.4.3 Group Purchasing/Order Aggregation

Group purchasing, or *order aggregation,* is a creative solution for incorporating new technologies into new construction and retrofit projects. Group purchasing eliminates several key barriers identified during technology demonstration projects, such as product coordination and high-cost mark-ups for small orders. By combining product orders from multiple campuses, participants may 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 new technologies without equivalent alternatives.

A combination of circumstances is necessary to facilitate a group purchase or order aggregation, since the facilitator is not doing the purchasing, but rather acting as a consolidator. Such a scenario occurred in 2004–2010 with the Program facilitating an order aggregation by several

[16] These video case studies can be viewed at cltc.ucdavis.edu/publication-type/video.

UC campuses from the original vendor of bi-level stairwell luminaires. Circumstances have not since been conducive to Program-facilitated group purchases or order aggregation.

CHAPTER 6: Program Impacts

This chapter provides an update of previous estimates of the California market potential of SPEED program technologies (Johnson et al. 2011; Brown et al. 2012). Progress toward achieving the market potential can now be assessed directly, through documentation of the significant energy-use reduction resulting from achieved or planned deployment of PIER technologies—deployment associated with some of the major incentive programs or reported by key manufacturers. This section updates the previous accounting of achieved or targeted savings. It also includes a new compilation of projected statewide energy savings from implementation of SPEED-supported updates to the 2013 Title 24 Building Efficiency Standards.

Indirect indicators of progress toward achieving market potential include:

- Engagement of new manufacturers,
- Inclusion in codes and standards or leading organization specifications,
- Further demonstration by utility emerging technology programs,
- Inclusion in general utility incentive programs, and
- Recognition through awards.

6.1 Market Potential of Program Technologies—Retrofit

One measure of the Program's potential impact is the California statewide energy savings that would result from achieving the market potential of the demonstrated technologies in retrofit applications. Table 11 provides estimates (based on 25 percent market penetration) for energy savings from a partial set of the Program technologies.

6.2 Technology Deployment to Date—Retrofit

The energy savings targeted or achieved by major implementation programs illustrates progress toward achieving the market potential of PIER technology. Table 12 outlines annual electricity and natural gas savings for several deployment programs enabled by SPEED Program technology transfer.

Monitoring-based commissioning (MBCx) continues to make up a large fraction of the achieved savings documented to date. The Program coordinates closely with the UC/CSU/IOU Partnership, and MBCx projects are a distinct element of the UC/CSU/IOU Partnership, so achieved savings totals for MBCx are convenient to tabulate. Preliminary accounting of the achieved savings for third-party MBCx programs is also available.

The accumulation of 10 years of MBCx projects in the UC/CSU/IOU Partnership totals 44 million kWh per year and 3.6 million therms per year. Adding savings achieved by third-party programs brings these totals to 60 million kWh per year and 4.5 million therms per year.

This is a significant fraction of the market potential of 615 million kWh per year and 15 million therms per year estimated, assuming 25 percent market penetration and modest energy savings per square foot. (Market penetration may now be higher for UC.) Scaled deployment of MBCx is making a significant dent in the market potential, in UC and CSU policy goals, and in California climate protection efforts.

Tracking achieved savings from other SPEED-supported technologies is not as easy. Technology is often not clearly labeled in UC/CSU/IOU Partnership or other program documentation. The adoption of SPEED-supported technologies has spread widely, spreading into a diverse set of programs and market sectors.

However it is possible to compile a partial accounting of achieved savings from a partial set of clearly labeled UC/CSU/IOU Partnership projects, estimates from the UC Davis Smart Lighting Initiative, documented savings from State Energy Program (SEP) American Recovery and Reinvestment Act (ARRA) programs, documented savings from other third-party programs, and information provided by a key vendor. (Adjustments were made to eliminate any potential double counting from crossover of these sources.) Documented achieved savings now total 128 million kWh per year and 5.6 million therms per year, with avoided costs of over $20 million per year. This is a good start toward the market potential of 3.6 million kWh per year and 97 million therms per year estimated assuming 25 percent market penetration. More savings targeted by planned projects are documented in Table 13.

The Program has also identified additional scaled deployment programs including, but not necessarily focusing on, PIER/SPEED technology. These are listed in Table 14, but not added to the achieved or targeted savings totals because it is not known how much of program savings was associated with new PIER/SPEED technology.

6.2.1 Financing Scaled Deployment—Retrofit

Substantial subsidies have financed the vast majority of scaled deployment documented to date. The most prominent subsidy programs are the UC/CSU/IOU Partnership and the American Recovery and Reinvestment Act (ARRA) State Energy Program (SEP) Energy Technologies Assistance Program (ETAP). The UC system has the strongest financing structure, with UC/CSU/IOU Partnership incentives combined with a robust internally financed low-interest loan program fully integrated into the debt management of the system and the campuses. California State University (CSU) has had substantial success with a combination of the UC/CSU/IOU Partnership and ARRA State Energy Plan ETAP incentives. In addition, local governments are taking advantage of ETAP. California State University and UC also occasionally use utility on-bill financing. California State University makes more use of on-bill financing, as UC prefers to use its internal financing as a part of its debt management. The biggest opportunity for expanding scaled deployment of new technology remains with the UC system because the internal bond-funded financing structure has the highest probability of enduring.

Table 11: Retrofit Market Potential for Technologies Demonstrated by SPEED Program (Partial)

PIER/SPEED Technology Assumptions	California Statewide Annual Retrofit Savings Potential (25% Market Penetration)			
	Electricity (million kWh/yr)	Natural Gas (million therms/yr)	CO_2e (metric tons/yr)	Energy Cost ($millions /yr)
Interior Lighting 60% savings for CEUS 2006 Large & Small Office, School, College	960		272,000	136
Exterior Lighting 60% savings for CEUS 2006 Large & Small Office, Warehouse, School, College, Health, Miscellaneous	401		113,000	40
Lighting Totals	**1,361**		**385,000**	**176**
Package Units—Advanced Retrofits 75% applicability to CEUS 2006 Small Office, School 74% ventilation savings	190		54,000	27
Wireless HVAC Retrofits 50% applicability to CEUS 2006 Large Office & College—60% ventilation, 14% cooling, 23% heating savings	231	4	89,000	36
Personal Comfort Systems CEUS 2006 Applicability: 90% Large Office, 60% Small Office, 30% College—42% cooling, 15% heating savings	295	72	465,000	93
General HVAC Totals	**716**	**76**	**608,000**	**156**
Kitchen Demand-Controlled Ventilation CASE Report (CUSCST 2011a) Savings of 31 kWh/gsf/yr and 0.32 therms/gsf/yr applied to 50% of CEUS 2006 Restaurant Floor Area	579	6	195,000	86
Data Center Wireless HVAC Controls 2012 CA Data Center Usage 7,780 million kWh (50% applicability, 15.2% savings)	296		84,000	42
Specialty HVAC Totals	**875**	**6**	**279,000**	**128**
Monitoring-Based Commissioning 1 kWh/gsf/yr and 0.025 therms/gsf/yr applicable to 50% of CEUS 2006 floor area	**615**	**15**	**254,000**	**98**
Program Totals	**3,567**	**97**	**1,526,000**	**558**

Notes:
gsf = gross square feet
0.00283 metric tons of CO_2e per kWh, 0.0053 metric tons of CO_2e per therm
$0.1418 per kWh (except exterior lighting at $0.1000/kWh), $0.705 per therm
CEUS = California Commercial End-Use Survey

Table 12: Achieved Savings of Deployment Programs and Product Lines Using PIER Technologies Demonstrated by the SPEED Program (Partial)

Deployment Program (Achieved Savings)	Annual Electricity Savings (kWh)	Annual Natural Gas Savings (therms)	Annual Energy Cost Savings [(1)]
Monitoring-Based Commissioning (MBCx) UC/CSU/IOU Energy Efficiency Partnership Program (savings achieved from 2004 to April 2014) http://www.uccsuiouee.org)	44,128,853	3,574,719	$8,777,648
Monitoring-Based Commissioning Third-Party Program, EnerNOC (PG&E Service Territory) High Tech and Commercial Facilities (preliminary)	2,516,566	285,089	$557,837
Monitoring-Based Commissioning Third-Party Program, EnerNOC (SCE Service Territory) Commercial Facilities (preliminary)	7,303,612	674,488	$1,511,166
Lighting UC Davis Smart Lighting Program Phase I	5,700,000	0	$808,260
Lighting: Other Interior UC/CSU/IOU Energy Efficiency Partnership Program 11 Projects	1,301,112	0	$184,498
Lighting: Other Garage, Exterior, & Roadway UC/CSU/IOU Energy Efficiency Partnership Program 3 Projects	1,283,066	0	$181,939
Lighting SEP ARRA Funding: ETAP – Energy Solutions (potential double counted projects excluded)	5,798,888	0	$822,282
Lighting Installations to mid-2014 (estimated) (potential double counted projects excluded)	43,876,481	0	$6,221,685
Wireless HVAC Controls UC/CSU/IOU Energy Efficiency Partnership Program 6 Projects	2,868,003	132,332	$499,977
Wireless HVAC Controls SEP ARRA Funding: ETAP – Energy Solutions (potential double counted projects excluded)	5,631,997	747,668	$1,325,723
Demand-Controlled Kitchen Ventilation UC/CSU/IOU Energy Efficiency Partnership Program 2 Projects	244,766	8,920	$40,996
Demand-Controlled Kitchen Ventilation Third-Party Program, GreenVent (PG&E Service Territory)	5,426,438	157,633	$880,600
Wireless Data Center Cooling Controls SEP ARRA Funding: Vigilent	2,313,524		$328,058
Total Savings Achieved by Deployments To Date	**128,393,306**	**5,580,849**	**$22,140,669**

Notes: Assumption - $0.1418/kWh, $0.705/therm

Table 13: Targeted Savings of Deployment Programs Using PIER Technologies Demonstrated by the SPEED Program (partial)

Deployment Program (Targeted Savings)	Annual Electricity Savings (kWh)	Annual Natural Gas Savings (therms)	Annual Energy Cost Savings [(1)]
Monitoring-Based Commissioning (MBCx): UC/CSU/IOU Energy Efficiency Partnership Program (projects in-progress to be completed by the end of 2015) http://www.uccsuiouee.org)	20,340,784	1,527,330	$3,961,091
Lighting UC Davis Smart Lighting Program Phase II (in-progress)	5,500,000	0	$779,800
Lighting UC Davis Smart Lighting Program Phase III (proposed)	4,852,261	0	$688,051
Lighting UC Davis Smart Lighting Program Phase (pending funding)	18,647,739	0	$2,644,249
Lighting: Other Interior UC/CSU/IOU Energy Efficiency Partnership Program 7 Projects	1,387,736	0	$186,781
Lighting: Other Garage, Exterior, & Roadway UC/CSU/IOU Energy Efficiency Partnership Program 3 Projects	3,801,940	0	$539,115
Demand-Controlled Kitchen Ventilation UC/CSU/IOU Energy Efficiency Partnership Program 1 Project	53,048	0	$7,522
Total Additional Targeted Savings (In Progress)	**54,583,508**	**1,527,330**	**$8,806,709**
Total Cumulative Savings Achieved and Targeted	**182,976,814**	**7,108,179**	**$30,947,378**

Notes:

1. Assumption: $0.1418/kWh, $0.705/therm

Table 14: Achieved Savings of Deployment Programs Using PIER Technologies Demonstrated by the SPEED Program

Deployment Program (Achieved Savings) [(2)]	Annual Electricity Savings (kWh)	Annual Natural Gas Savings (therms)	Annual Energy Cost Savings [(1)]
Municipal and Commercial Building Targeted Measure Retrofit Program—SEP/ARRA: Downtown Oakland Targeted Measure Saturation Program	4,500,000	69,000	$686,745
PG&E High Performance Office Lighting Systems Third-Party Program	13,485,768	0	$1,912,282

Notes:

1. Assumption: $0.1418/kWh, $0.705/therm
2. These mainstream implementation programs were initiated at least partly as a result of PIER SPEED Program activities and are focused on PIER technology. However, these programs do not use PIER technology exclusively, and the fraction of PIER content is to be determined.

6.3 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.

6.3.1 Lighting Technologies

Public Interest Energy Research program funding of the combination of the CLTC and SPEED for the last 10 years has had a profound impact on the number of lighting manufactures making more efficient, smart, and adaptive lighting products. Along with development of LED lighting technology, this has accelerated the pace of innovation in the lighting industry. New manufacturers and product lines are now too numerous to mention. The participation of many vendors in the market has lowered prices, facilitating inclusion of new technology in major deployment programs and allowing incorporation of basic aspects of some new technology in updates to building standards.

The rapid progression of the market has seen Adura, the original SPEED program partner for adaptive lighting control, purchased by Acuity Brands. Acuity Brands is also now offering products using organic LED technology. Enlighted is another important new vendor for adaptive lighting controls (see Table 9).

6.3.2 HVAC Technologies

Additional manufacturers are developing high performance HVAC rooftop package units in conjunction with the Western Cooling Challenge. The Trane DC Voyager is the latest product to be certified and is considered to have the best prospects for significant market penetration.

6.4 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 Standards process is a major user of PIER-developed information, and the Program has contributed to advances in the lighting sections of the Standard. Program results can also inform appliance standards (e.g., California Title 20), HVAC standards (e.g., ASHRAE 90.1).

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

6.4.1 California Energy Efficiency Standards

The work of the Program has had a significant impact on both Building Energy Efficiency Standards (Title 24) and Appliance Efficiency Regulations (Title 20) in California. Table 15 provides a partial accounting of energy savings estimates from SPEED-supported updates to 2013 Title 24. Projected statewide annual savings from demand-controlled commercial kitchen ventilation and certain lighting measures totals more than 160 million kWh per year and more than 700 thousand therms per year, with avoided energy costs of over $20 million per year.

Table 15: Projected Savings from New Provisions of 2013 Title 24

End-Use/ Codes And Standards Enhancement (CASE) Report/ Measure(1)	Annual Electricity Savings (kWh)	Annual Natural Gas Savings (therms)	Annual Energy Cost Savings (2)
Lighting Parking Garage Lighting and Controls CASE Report (CUSCST 2011b) Lighting Power Allowance, Occupancy Controls, Daylighting Controls	55,377,000		$7,852,459
Lighting Automated Lighting Controls and Switching Requirements in Warehouses and Libraries CASE Report (CUSCST 2011c) Library Stacks	70,000		$9,926
Lighting Indoor Lighting Controls CASE Report (CUSCST 2011d) Office "LPD Reductions"	14,700,000		2,084,460
Lighting Lighting in Multifamily and Hotel Corridors CASE Report (CUSCST 2011e) Automated Lighting Controls and Switching Requirements	23,600,000		$3,346,480
HVAC Specialty Kitchen Ventilation CASE Report (CUSCST 2011a) Measure 4: Commercial Kitchen System Efficiency Options (Demand-Controlled Kitchen Ventilation)	72,000,000	742,000	$9,019,110
Total Savings Projected	**165,747,000**	**742,000**	**$22,312,435**

Notes:

1. Savings as estimated and directly reported as statewide energy savings for listed measures in the respective Codes and Standards Enhancement (CASE) Report. Only measures strongly attributable to the SPEED program and with statewide savings estimates are listed.
2. Assumption: $0.1418/kWh, $0.705/therm

6.4.1.1 Title 24

Lighting

The SPEED program worked closely with the Title 24 process and has been instrumental in numerous enhancements to the lighting provisions (Johnson et al. 2011; Brown et al. 2012). The 2013 Title 24 lighting updates are very significant and include dimmable ballasts or drivers, bi-level occupancy controls for interior and exterior spaces, additional daylighting controls, and other efficiency improvements. Also, the threshold for a renovation/retrofit project to trigger code compliance has been significantly lowered. Lighting updates are detailed in several CLTC publications available on its website at: http://cltc.ucdavis.edu/article/new-title-24-resources.

Even with these significant changes in Title 24 for 2013, many best practice SPEED lighting technologies provide performance that offers an additional 20 to 50 percent savings. Examples include corridor, exterior, office, and classroom lighting using full-range dimming ballasts, more granular controls, and advanced control strategies.

Heating, Ventilation, and Air Conditioning

With the release of the 2013 Title 24 Building Energy Efficiency standards, changes were made that shifted some technologies from candidates for incentives to required measures. Key areas included changes to demand-controlled ventilation requirements for small RTUs (Sections 140.4.c and140.4.e), in parking garages (Section 120.6.c), and for commercial kitchen ventilation (Section 140.9.b). Data centers were required to incorporate economizers (Section 140.9.a). Additionally, changes were made to the requirements for how VAV systems work in laboratory environments (Section 140.9.c).

SPEED-related activities, especially in the areas of RTU retrofit efficiency controllers and climate-appropriate evaporative air conditioning improvements will provide beneficial data for the development and support of new Title 24 standards.

6.4.1.2 Title 20

Lighting control devices are now regulated in Title 20, in addition to the applications standards in Title 24. This includes acceptance testing for controls required for exterior luminaires—consistent with language in Title 24 stipulating that all exterior lighting for commercial applications include adaptive lighting controls and lowered light levels during periods of low occupancy. SPEED program and other CLTC field data supported development of these requirements.

SPEED and other CLTC field data is also supporting a pending proposal for update of Title 20—to include control of streetlights.

6.4.2 Other Standards, Guidelines, Specifications, and Initiatives

Following successful PIER lighting demonstrations, hosts often implement lighting standards or standards revisions to incorporate demonstrated technologies in future retrofit and new construction projects. Several organizations adopted specifications based on PIER technology in 2004–2010 (Johnson et al. 2011).

Some more recent examples include the adaptive and network controlled lighting at UC Irvine, dimmable exterior lighting and networked controls for streetlights at UC Santa Barbara, adaptive LED interior lighting for Student Affairs facilities at UC Santa Barbara, and the Smart Lighting Initiative at UC Davis.

The UC Davis Smart Lighting Initiative projects are based on innovations developed or refined by CLTC designers and engineers and implemented by UC Davis Facilities Management. Many of the technologies employed at UC Davis were developed in partnership with PIER and demonstrated by the Program.

6.5 Utility Adoption: Partnerships and Programs

Program results have been utilized by 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.

6.5.1 Investor-Owned Utility Partnerships

The Program has been coordinated with the UC/CSU/IOU Partnership since the inception of both in 2004. See Chapters 3.1 and 5.1 for more information. The CCC/IOU Energy Efficiency Partnership was also linked to the coordination of program demonstrations on community college campuses (Johnson et al. 2011).

6.5.2 Utility Emerging Technology Demonstrations

Some lighting and HVAC demonstration activities completed under this Program fed directly into California utility emerging technology 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.

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

One direct collaboration with a utility ET program was active in 2012–2014. The Program is partnering with Southern California Edison for the zero net energy (ZNE) retrofit of the UC Santa Barbara Recreation Center. The lighting part of this project was installed in 2014. More details can be found in Attachment V.

In addition to ET projects carried out with the support of CLTC and PIER, a number of demonstration projects have been carried out for Utility ET programs independent of PIER partnership. Although these projects are carried out without the direct support of the Program, they often demonstrate products developed or demonstrated by the Program at earlier times.

6.5.3 Other Utility Projects and Programs

Investor-Owned and Public utilities offer a wide range of rebates and incentives for energy-efficient lighting, including incentives for dimming ballasts, bi-level occupancy controls, and efficiency above the current Title 24 standards. Many also offer incentives for LEDs that are

Design Light Consortium-listed and on a utility-approved list for incentives. Many SPEED lighting technologies qualify for utility incentives.

6.5.4 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 Tables 9, 10, and 11.

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

The California 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 delivered the Program. Many of the IOLS, ICLS, bi-level lighting, daylight controls, and other PIER-developed solutions were anticipated to be used in this program.

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

The GreenVent for Energy Efficient Kitchens program was a turnkey program to deliver substantial energy savings by offering incentives for the installation of demand ventilation control in commercial food service facilities.

6.5.4.3 Monitoring-Based Commissioning Third-Party Programs

The UC/CSU/IOU Partnership successfully piloted MBCx as a major program element since its inception in 2004. The CCC/IOU Partnership also began funding MBCx projects in 2006.

Commissioning consultants working on UC/CSU/IOU Partnership projects in 2004–2008 proposed third-party MBCx programs for the 2009–2011 energy efficiency program cycle in the PG&E and SCE service territories. The achieved savings have been lower than the targets, partly because of the slow down in economic activity during the inception of the programs. The state of the art in IT infrastructure, metering, cloud computing, and data analytics has improved since the inception of the programs. While the relatively sophisticated higher education facilities environment was successful with MBCx before these advances, they may be necessary for widespread commercial adoption. Details can be found in Table 9.

6.6 State Energy Program/American Recovery and Reinvestment Act Programs

Public Interest Energy Research technology figured prominently in energy efficiency programs awarded funding by the 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. Achieved savings for these programs are included in Tables 9 and 11.

6.6.1 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 (MCBTMR) 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 was a team member for the proposal by Energy Solutions, whose award for its Energy Technology Assistance Program served municipalities in the Greater San Francisco Bay Area, Southern California, and Sacramento.
- Quantum Energy Services & Technologies also used PIER technologies proven through the SPEED Program for the Downtown Oakland Targeted Measure Saturation Project.

The PIER lighting technologies included in the MCBTMR 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

For details of the savings achieved by the MCBTMR program with PIER/SPEED technologies, please see Table 9. Because of its success, additional funding was allocated to this program, along with an extension to the limit of the ARRA funding.

6.6.2 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 SPEED program. The demonstration of the technology at the California Franchise Tax Board facility in Sacramento led to a successful proposal for ARRA State Energy Program funds for retrofit of the technology in eight State of California data centers. Details of energy savings can be found in Table 9.

6.7 California Public Utilities Commission (CPUC) Interactions

Many PIER/SPEED technologies are included in the CPUC 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 is based on a goal of shifting California from standard practices to best practices (CPUC 2010). The 2010 Lighting Technology Overview produced for the CPUC uses the same PIER technologies as cited in the 2010–2012 Statewide investor-owned utility LMT plan as examples of the 10-year results from supporting best practices versus standard practice (CLTC 2010).

Motivated by the CPUC's plan, UC Davis instituted the Smart Lighting Initiative to reduce the campus's electricity use for lighting by 60 percent. Please see Sections 6.2 and 6.4.2 for more information.

6.8 Awards

6.8.1 UC and CSU Best Practice Awards

The University of California and California State University systems honor campuses with Best Practice Awards in a number of energy efficiency categories as a part of the California Higher Education Sustainability Conference and in conjunction with the UC/CSU/IOU Partnership. The SPEED Program projects have won a number of these awards[17].

6.8.1.1 2012 UC and CSU Best Practice Awards

San Diego State University and UC San Diego won the HVAC retrofit awards in 2012 for constant-volume to variable-air-volume conversions using Vigilent Technology similar to that demonstrated in previous SPEED Program phases.

The University of California Santa Cruz, won the lighting retrofit award in 2012 for its Phase I and II campus-wide lighting retrofit using bi-level controls and other SPEED Program technologies.

6.8.1.2 2013 UC and CSU Best Practice Awards

The University of California, Davis, won the 2013 lighting retrofit award for institutional-level (campus-wide) adaptive exterior lighting consisting of 1,500 network-controlled dimmable LED fixtures. Please see Attachment II for a case study of this project.

California State University, Fullerton, won the 2013 lighting retrofit award for a campus-wide project consisting of adaptive interior and exterior lighting including some network control and LED-technology—technologies demonstrated by the SPEED Program.

6.8.1.3 2014 UC and CSU Best Practice Awards

California State University, Dominquez Hills, won the 2014 lighting retrofit award for wireless networked adaptive interior lighting controls, technology demonstrated by the SPEED Program.

The University of California, Santa Cruz, won the 2014 lighting retrofit award with an in-house designed project integrating LED retrofits and networked lighting controls based on technology previously demonstrated by the SPEED Program.

[17] Projects are documented at: http://greenbuildings.berkeley.edu/best_practices.htm.

6.8.2 Other Awards

The Illuminating Engineering Society-recommended practice for Daylighting Buildings (RP-5-13) was selected for top honors at LightFair 2014 for the "Research Publications, Software and Measuring Devices " category. The CLTC was a principal author, and PIER/SPEED daylighting sensors, controls, and field data are a key part of the new recommended practices.

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 and sustained demonstration / market adoption program can significantly accelerate the market penetration of these products. The State Partnership for Energy Efficient Demonstrations (SPEED) Program effectively partners with university RD&D centers and employs a variety of tools, including case studies, business cases, guide specifications, technology catalogs, virtual tour videos, other training and education materials, codes and standards support, and other technology transfer resources, to cross the "valley of death" that often stalls new technology. Development of strong partnerships with market participants and a variety of methods has led to Program success.

The Program has been highly successful in facilitating integration of new technology into utility energy efficiency and economic-stimulus programs, as well as in stimulating manufacturers to offer more new technology in their product lines. The Program has enabled the development of products for an expanding set of end-use applications with more market potential. These market adoption successes have lead to scaled deployment of PIER technology solutions and to incorporation into codes and standards. The Program helped catalyze a rapidly increasing pace of innovation in the lighting industry, now leading to opportunities to drastically decrease lighting energy use in buildings.

There already has been enough market penetration to directly validate the investment in the Program. Documented annual savings from avoided energy use is now more than double the total program cost and growing. Multiple technologies are now benefitting California energy consumers earlier than they would have without the Program.

7.1 Lessons Learned/Accelerating the Pace of Technology Development

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 adaptive interior and exterior lighting products derived from bi-level exterior lighting products, which were derived from bi-level stairwell products.

Partly due to Program efforts, but also driven by the emergence of solid-state lighting (i.e., light emitting diode) technology and an urgent need for climate protection solutions; the lighting industry is undergoing a transformation to a "Silicon Valley" pace of innovation. The HVAC industry is poised for similar innovation acceleration, also partly due to Program efforts. The increasing pace of innovation in energy efficiency technology will necessitate an evolution of demonstration program activities, to stay ahead of the shorter product innovation cycles.

7.2 Working in the Various Market Sectors

Higher education campuses provide a good setting for technology demonstration. Each public system (UC, CSU, and CCC) organization has its own needs, priorities, and procedures. The campuses also include several different markets within such as the main campus, the auxiliaries, and new construction/capital projects. 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 system wide management that minimizes the effort needed to organize demonstration activities.

The UC system has the strongest financing structure for scaled deployment of new PIER technology with the combination of substantial UC/CSU/IOU Partnership incentives and an internal low-rate loan program fully integrated into the system and campus debt management. The Program also has documented substantial scaled deployment of new PIER technology by the CSU system and local governments. Extending success with these organizations may depend on identifying new financing structures. Part of the deployment success depended on ARRA State Energy Plan ETAP funding. Increased outreach to local governments could be an effective direction for future Program efforts.

7.3 The Role of University Centers

University RD&D centers play a dual role in the Program process. First, they provide a stream of new best practice technologies and solutions for the Program. Second the centers are 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 research, development, demonstration, and evaluation of new technologies needed for California to meet aggressive sustainability goals.

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 activities have been recognized with multiple awards. The result has been accelerated market adoption of new energy efficiency technologies and best practice solutions. The Program has documented substantial savings accruing to California consumers from the scaled retrofit deployment of demonstrated PIER technologies now at an annual rate double the entire investment in the Program. An equivalent level of savings is projected from deployment of some Program technologies as new requirements of the 2013 Title 24 Building Energy Efficiency Standards.

7.5 Future Efforts

The SPEED Program will continue with limited activity associated with the project "Changing the Rules: Innovative Low-Energy Occupant-Responsive HVAC Controls and Systems." However, new funding will be needed for the Program to continue to facilitate market adoption of other new technology through ongoing demonstrations, assistance with pilot-scale deployments, special technology transfer projects, and other market adoption acceleration activities—maintaining momentum toward California's expansive and comprehensive goals.

New funding can be used effectively to achieve an even more rapid and widespread adoption of PIER technology and progress toward state goals. The biggest opportunity for expanding scaled deployment of new PIER technology is likely to be associated with the UC system because of its new 2025 operational carbon neutrality goal and because the UC energy efficiency retrofit financing structure has the highest probability of enduring. California State University and local government organizations are also potential venues. Additional resources allocated to the SPEED Program could allow expansion of demonstrations of new EPIC technologies; more assistance in scaled deployment of the proven new technologies; integration of PIER and EPIC technologies into zero net energy projects and goals, and more outreach to new construction and major renovation programs.

Continued funding for research and development efforts will also be necessary to maintain the progression of market-driven applications of technology for new energy efficiency products and services into the marketplace. With its extensive experience with demonstration and deployment, the Program is positioned to inform effective R&D efforts.

The Program process could be replicated for other California Energy Commission programs or in other states.

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GLOSSARY

ACEEE	American Council for an Energy-Efficient Economy
AEC	Architectural Energy Corporation
AFB	Air Force Base
ARRA	American Recovery and Reinvestment Act
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
C	Carryover Project
CASE	Codes and Standards Enhancement
CBE	Center for the Built Environment
CCC	California Community Colleges
CEC	California Energy Commission
CEUS	California Commercial End-Use Survey
CFL	Compact Fluorescent Lamp
CDPH	California Department of Public Health
CHES	California Higher Education Sustainability
CIEE	California Institute for Energy and Environment
CLTC	California Lighting Technology Center
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent as greenhouse gas
CPUC	California Public Utilities Commission
CSU	California State University
CV	Constant Volume
DART	Discharge Air Regulation Technique
DAS	Data Acquisition System
DASH	Datacenter Automation Hardware and Software
DGS	Department of General Services
DOAS	Dedicated Outside Air System

DOE	United States Department of Energy
DX	Direct Expansion
ECM	electronically commutated motors
EIS	Energy Information System
EMCS	Energy Management and Control System
ESCOs	Energy Service Companies
ET	Emerging Technology
ETAP	Energy Technologies Assistance Program
FSTC	Food Service Technology Center
FTB	Franchise Tax Board
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
gsf	Gross square foot
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
M&V	monitoring and verification
MCBTMR	Municipal and Commercial Building Targeted Measure Retrofit

MDL	Micro Data Logger
MBCx	Monitoring-Based Commissioning
NAM	Newcomb Anderson McCormick
NAWS	Naval Air Weapons Station
NEEA	Northwest Energy Efficiency Alliance
NEMA	National Electrical Manufacturers Association
NYSERDA	New York Energy Research and Development Authority
PCS	Personal Comfort System
PG&E	Pacific Gas and Electric
PIER	Public Interest Energy Research
RD&D	Research, Development and Demonstration
RTU	Rooftop unit
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
SEP	State Energy Program
SMUD	Sacramento Municipal Utility District
SPEED	State Partnership for Energy Efficient Demonstrations
SPOT	Sensor Placement Optimization Tool
SVLG	Silicon Valley Leadership Group
T24	Title 24
T&E	Training and Education
UC	University of California
UCOP	University of California Office of the President
USN	United States Navy
VAV	Variable Air Volume
WCEC	Western Cooling Efficiency Center
WCC	Western Cooling Challenge

WIPAM	Wireless Integrated Photosensor and Motion Sensor System
ZNE	Zero Net Energy