# PARNTERSHIPS FOR ENERGY-EFFICIENT LIGHTING

## MULTIPLE CAMPUS AWARD NO. C-08-15

CLTC
CALIFORNIA LIGHTING TECHNOLOGY CENTER



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## PREPARED FOR:

California Institute for Energy and Environment

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## ABOUT CLTC

The California Lighting Technology Center's mission is to stimulate the development and application of energy-efficient lighting by conducting technology development and demonstrations, outreach and educational activities, in partnership with lighting manufacturers, lighting professionals, the electric utility community and governmental agencies. CLTC was established as a collaborative effort between the California Energy Commission and UC Davis, with support by the U.S. Department of Energy and the National Electrical Manufacturers Association (NEMA).

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# 1.0 EXECUTIVE SUMMARY

The California Lighting Technology Center (CLTC) was established through a collaborative three-year effort between the Public Interest Energy Research (PIER) program of the California Energy Commission and the University of California, Davis (UCD).The CLTC mission is to advance, facilitate, and accelerate the development and commercialization of energy-efficient lighting technologies for interior and exterior applications. Working with regulatory agencies, utilities, manufacturers, universities, state agencies, and end users, CLTC has evolved into a central, research-based organization that addresses a wide variety of lighting issues through research, development, demonstration, outreach, education, and training. All of these activities position CLTC as a premier institution within the academic and professional lighting community. CLTC is fortunate to have continued support from its valuable partners and, as such, many groups were actively involved in developing the following research, demonstration, and outreach project portfolio.

The objective of multiple campus award no. C-08-15, a partnership between California Institute for Energy and Environment (CIEE) and CLTC, was to identify and develop a portfolio of coordinated projects and activities that will be CLTC's primary focus over its next three years of operation. The proposed project portfolio will directly support the Energy Commission's PIER mission and shall be built on the key successes and activities undertaken at CLTC since its inception in 2004. Many of the projects and activities contained in this report were formally funded through Interagency Agreement 500-08-053, between the Energy Commission and CLTC. Some activities, such as ongoing support for utility emerging technology programs, have been refined and funded through other sponsors.

CLTC expects its three-year research plan to focus on four core activities: technology development, technology demonstration, lighting codes and standards support, and technology transfer to market. Each of the core areas will be supported by multiple projects, most conducted in partnership with industry, utilities, and other academic institutions. This report addresses each of the five tasks outlined in C-08-15 and includes planned as well as completed activities. The culmination of this agreement is the formal award of a $3.2 million research package that addresses the core topics detailed in this report. This funding is a direct result of the support provided by the California Energy Commission, CIEE, NEMA, and CLTC's industry partners.

# 2.0 PROJECT BACKGROUND

CLTC has established strong partnerships with the lighting industry through a successful affiliates program as well as through joint proposals for the development and demonstration of new energy-efficient lighting technologies. Moreover, it has established strong connections with California universities, colleges, and government facilities for installation and field testing of new energy-efficient lighting technologies.

CLTC has been involved in the development of multiple energy-efficient lighting technologies for various applications, ranging from bi-level luminaires for bathrooms and parking garages, to commercial office lighting, and adaptive exterior lighting for recreation areas. Moreover, CLTC has been involved in technology demonstrations, in partnership with PIER and California utilities.

CLTC also has been successful in developing an undergraduate curriculum in lighting education and training as part of the UCD Design Program with courses in lighting and daylighting. Some lighting design courses are sponsored by the lighting industry. In addition, CLTC has initiated successful graduate lighting education as part of the UCD Design Program, as well as fostered collaboration with the UCD College of Engineering through an industry-sponsored fellowship for graduate studies in lighting controls.

All of these activities position CLTC as a premier institution within the academic and professional lighting community. CLTC is fortunate to have continued support from its valuable partners.

# 3.0 PROJECT OBJECTIVES

The objective of multiple campus award no. C-08-15 was to identify and develop a portfolio of coordinated projects and activities that will be CLTC's primary focus over its next three years of operation. The proposed project portfolio will directly support the Energy Commission's PIER mission and shall be built on the key successes and activities undertaken at CLTC since its inception.

Specific tasks have been developed directly from discussions with the Energy Commission, CIEE, state and local agencies, utility partners, and with the support of the NEMA directorate. The objective of the following roadmap is to produce a group of products, technologies, and knowledge that meet the PIER goals of advanced technology development, reduced technology cost, diversity of commercially available products, compatibility of solutions, and emphasis of long-term sustainability through energy efficiency. It also will address the important objective of strengthening California's economy by creating green jobs through partnerships with lighting industry, lighting professionals, the electric utility community, residential and commercial builders, the Energy Commission, and other governmental agencies.

# 4.0 PROJECT OUTCOMES

## 4.1 TASK 1 – PIER LIGHTING TECHNOLOGY PORTFOLIO

Research and development are core activities for CLTC. In an effort to expand energy-efficient lighting into new applications and markets, CLTC, in partnership with utility, industry, and demonstration partners, identified a suite of 15 projects that deserved pursuit over the next three years. These projects represent the evolution of basic lighting concepts into advanced, energy-efficient alternatives that will transform the residential and commercial markets in the years to come. Successful development and demonstration of these technologies is expected to catalyze industry to adopt similar concepts and launch successful derivative products. This model of research, demonstration, and market transformation lies at the heart of PIER, and CLTC looks forward to expanding the PIER product portfolio into new applications.

The following 15 development projects are intended to expand the PIER lighting portfolio in three key areas: daylighting, interior lighting, and exterior lighting. Most projects build on previous PIER-sponsored lighting research. For example, CLTC plans to develop a wall-wash luminaire for task-ambient lighting systems that will complement existing task-ambient lighting systems such as the Integrated Office Lighting System (IOLS), which was developed under a previous PIER award. A full description of each of these technical development projects may be found in Appendix A – PIER Technology Roadmap, along with a schedule of deliverables and project budget.

### 4.1.1 DAYLIGHTING AND FENESTRATION

- Commercial Dual-Loop Lighting Controls for Skylight Applications
- Smart Windows & Skylights
- Dual Photosensor Controls for Side-Daylighting Applications
- Daylight Optimization for Skylight Applications
- Solar Canopy for Core Daylighting

### 4.1.2 EXTERIOR LIGHTING

- High-Efficiency Bi-level Smart Wall Packs
- LED / Induction Longevity in Exterior Applications
- Smart Exterior Dark-Sky Friendly, Historically Accurate Lighting
- Side Projecting LEDs with PV Power and Control

### 4.1.3 INTERIOR LIGHTING

- Retrofit LED Downlights
- Digital Open-Source Lighting Controls Commissioning Tool
- Wall Wash for Task-Ambient Demand Responsive Ambient Lighting
- Solid-State Luminaires for High Bay, Poles, and Office Applications
- OLEDs for Office Ambient Lighting
- Next-Generation LED Residential Lighting and Manufacturer Training

## 4.2 TASK 2 – ENERGY-EFFICIENT PARTNERSHIPS

CLTC sits at a crossroads of academia, industry, and government. As such, CLTC is uniquely poised to build and strengthen relationships between PIER lighting research, academic institutions, and California government agencies. CLTC has demonstrated success in fostering energy efficiency among these groups. For example, CLTC completed a small exterior lighting demonstration in 2007 at San Francisco State University (SFSU). This project, conducted as part of the PIER lighting demonstration program, consisted of demonstration of four Integrated Classroom Lighting Systems (ICLS), a product developed by Finelite and CLTC with additional assistance from PIER. After this demonstration, SFSU adopted the ICLS as its classroom lighting standard, which institutionalized the concept of advanced lighting controls, plug-in-play compatibility, and energy-efficient luminaires at this campus. Such success stories build the foundation for future efforts with other key California partners. The following group of activities will identify and develop these partnerships to further expand knowledge and implementation of energy-efficient

lighting products and practices across California. A full description of each of the projects contained in the demonstration roadmap may be found in Appendix B – Demonstration Roadmap.

### 4.2.1 CALIFORNIA DEPARTMENT OF GENERAL SERVICES

California is one of the largest building owners in the state. The California Department of General Services (DGS) maintains a wide range of facilities for the state of California. These facilities include office buildings, parking garages and supply warehouses. DGS buildings represent an excellent demonstration and technology validation opportunity for emerging, energy-efficient lighting products. CLTC expects DGS partnerships to include development of lighting design manuals, employee training programs, installation procedures, and economic analysis to support widespread implementation of demonstrated technologies.

### 4.2.2 CALIFORNIA COLLEGES & UNIVERSITIES

The Energy Commission's PIER program sponsors the development and demonstration of energy-efficient building technologies. Over the past several years, CLTC and CIEE have developed strategic partnerships with the University of California (UC), California State University (CSU), and California Community Colleges (CCC). These partnerships include a series of demonstration projects coupled with programmatic support to ensure continued deployment of energy-efficient technologies and practices across California. To date, more than 30 demonstration sites throughout the state have been completed and monitored. This effective program is a critical step in moving viable technologies from the research laboratory to the marketplace. CLTC will continue to support and expand lighting demonstration programs with California universities and colleges. In particular, CLTC plans to forge new relationships with CCC, including direct demonstration projects with the Los Angeles Community College District (LACCD) and Peralta Community College District (PCCD).

### 4.2.3 PUBLIC / PRIVATE PARTNERSHIPS

CLTC works closely with many private entities to conduct energy-efficient lighting research. These groups provide a critical component of many research projects conducted at the Center. CLTC has incorporated private manufacturing partners in all of the technical development projects described in this report, and will continue to leverage its affiliate partners and others in future projects. Some key partnerships that demonstrate the types of entities, which will be engaged for existing and future projects, are:

- Natural Capitalism
- Wal-Mart
- City of Santa Monica
- Wide-Lite
- UCD Design Services

## 4.3 TASK 3 – UTILITY PARTNERSHIPS

Through research agreements and affiliate partnerships, CLTC has formed strong relationships with four major California utilities: Pacific Gas & Electric (PG&E), Sacramento Municipal Utility District (SMUD), San Diego Gas & Electric (SDG&E), and Southern California Edison (SCE). CLTC will work with these utility partners to identify promising lighting technologies; conduct peer reviews for reports and papers; complete or assist with emerging technology assessments; conduct laboratory testing and evaluation; participate in the codes and standards development process; conduct education and training events; and leverage utility resources to further develop innovate lighting and daylighting technologies. A full description of each of the projects and activities outlined for CLTC's utility focus may be found in Appendix C – Utility Roadmap.

### 4.3.1 EMERGING TECHNOLOGY PROGRAMS

CLTC supports California Utility Emerging Technology (ET) programs in a variety of ways. These include providing general guidance to ET initiatives; conducting lab and field evaluations of emerging technologies; advising on new energy-efficient lighting and daylighting technologies; producing outreach documents on various lighting technologies; and peer review of documents including ET test plans and assessment reports. CLTC expects that many of the technologies developed over the next three years will enter the ET pipeline, where they will be vetted for utility rebate and incentive programs. CLTC will continue to support these activities, as appropriate through its Energy Commission sponsorship, and also will work directly with utilities to leverage all available energy-efficiency resources.

### 4.3.2 UTILITY-SPONSORED RESEARCH AND DEVELOPMENT

California utilities dedicate funds each year to research and development of energy-efficient lighting technologies. CLTC will continue to work with these groups to fully leverage the research funding provided by the Energy Commission and its private partners. The following outline includes research projects in line with the PIER mission, and projects intended to supplement the PIER lighting portfolio. Some activities, such as Smart Demand Response Lighting Systems for Commercial Buildings, represent coordinated efforts among CLTC and all utility partners. By engaging in utility-sponsored research, CLTC delivers technology that will be embraced statewide by key partners with outreach and customer bases that range well beyond traditional academic boarders.

PG&E
- Super Lamp Development
- Lighting Technology Fact Sheets
- Title 24 Residential Lighting Class Instruction
- Smart Demand Response Lighting Systems for Commercial Building

SMUD
- Smart Demand Response Lighting Systems for Commercial Buildings
- LED Replacements for Linear Fluorescent Lamps

SDG&E
- Backlit Menu Boards Evaluation
- Hotel Lighting Controls Study
- Product Evaluation of the Parans Solar Lighting System
- Electronic HID Ballast Longevity & Compatibility Testing
- LED Track Lighting Development and Demonstration
- Smart Demand Response Lighting Systems for Commercial Buildings

SCE
- HID Lamp Life Testing
- Controllable Lighting Roundtable Series
- Smart Demand Response Lighting Systems for Commercial Buildings

## 4.4 TASK 4 – RESEARCH SUPPORT FOR BUILDING AND APPLICANCE CODES AND STANDARDS

In addition to successful research, development, and technology demonstration, CLTC continues to provide technical assistance regarding building and appliance codes and standards. Demonstrated energy-efficient lighting products and practices must have an advocate to achieve inclusion in state energy codes and lighting standards. The following group of activities is intended to influence existing and future energy codes, lighting standards and recommended practices. Details of these activities may be found in Appendix D - Codes & Standards Roadmap.

### 4.4.1 UNIVERSITY OF CALIFORNIA, IRVINE – APPLIANCE CENTER

CLTC, a university-based research lab with a solid connection to industry partnerships, represents a success story for the UC system. CLTC staff members regularly field inquiries on how to develop utility and industry relationships that lead to favorable results for both CLTC and its partners. The University of California, Irvine is interested in developing an appliance center based on CLTC's operating model. The UC Irvine appliance center will support Title 20 and 24, and statewide utility energy-efficiency goals. Throughout this contract, CLTC staff has attended and hosted roundtable discussions with UC campus representatives, utility partners, and Energy Commission representatives to plan for the appliance center's initial launch. UC Irvine is preparing a submittal to PIER for funding to establish the center. CLTC will continue to provide support through the critical start-up period. Southern California Edison has a strong interest in supporting the center's development, and other utilities are expected to follow once the proposal is further along.

### 4.4.2 CALIFORNIA ENERGY CODE

The success of California energy codes is largely dependent on the combination of high-efficacy lighting sources and controls, not just the inclusion of one or the other. CLTC continues to offer insight to the Commission and act as a liaison with industry stakeholders as to how Title 20 and Title 24 can continue meeting and exceeding code goals. Ongoing research at CLTC will form the foundation for future technology that will impact California energy codes.

For example, to expand upon the success of its exterior lighting initiative, which helped motivate changes in Title 24 code, CLTC has targeted lighting in hallways and common areas as the next large opportunity for statewide reduction in energy use. A workshop held at CLTC to analyze the energy use at UC Davis in these areas revealed that the campus uses about 50 million kWh annually for lighting. A total of 14,778,053 kWh are used for lighting campus corridors. This number presents an opportunity for immediate reduction. If UC Davis is used as a base case for other campuses, the opportunity is clearly one worth pursuing. To encourage the installation of occupancy responsive controls in these areas, CLTC staff met with utility partners to fund a large campaign to demonstrate the scope of the savings opportunity and to gather momentum toward retrofits that will provide immediate savings. CLTC plans to continue this effort into 2010 by securing funding from SMUD, PG&E, SCE, and SDG&E. Additionally, CLTC staff continues to meet with industry stakeholders and policy makers to develop the next generation of Title 24 code language. The process of developing the language in a way that appeals to manufactures and specifiers is critical to meeting Title 24 and AB 1109 goals.

### 4.4.3 LIGHTING STANDARDS

As a part of CLTC's effort to incorporate energy-efficient lighting into UC campuses statewide, an exterior lighting plan was presented to UC vice chancellors on June 11. CLTC developed partnerships with several of the attendees before the meeting, and the Center continues to build these relationships to encourage the system-wide adoption of the practices outlined in the plan. The UC Davis exterior lighting retrofit continues to serve as a case study for the energy savings potential and economic feasibility of a project of this size. The plan was presented again at the Campus Lighting Retrofit Forums in July, with representatives of the UC system speaking on forum panels to show support for the measures from the UC facility management perspective. CLTC's relationships with UC leadership are critical to continue working with the UC system to demonstrate technologies and encourage the system-wide adoption of exterior lighting best practices.

## 4.5 TASK 5 – TECHNOLOGY TRANSFER TO THE MARKETPLACE

CLTC is dedicated to successful introduction and adoption of energy-efficient lighting products to the California market. CLTC aims to shape and support technology development and early deployment efforts to accelerate the technology diffusion process. The ultimate outcome of future market connections projects is broadening market adoption of the energy-efficient lighting products developed through PIER

and utility-sponsored research, including codes and standards covering qualified products. Given the range of products slated for development over the next three years, technology transfer activities will be unique and focused toward the appropriate stage of product development and market readiness. For most technologies, additional market connection activities will be required beyond the timeline of the three-year agreement. A full description of technology transfer activities is contained in Appendix E - Technology Transfer Roadmap.

### 4.5.1 PROGRAMWIDE MARKET CONNECTIONS

CLTC shall coordinate market connection activities among manufacturers, product developers, and utilities to enhance their product business case, market appeal and incentive packages. This work will include alliances with key institutions to support market adoption and expand market opportunities. CLTC will work to build relationships with California utility programs aimed at energy efficiency and demand response. Technologies will be integrated into emerging technology programs, which will facilitate technology transfer and market adoption.

### 4.5.2 UTILITY-INDUSTRY FORUM

CLTC and co-host UC Irvine hosted two seminars with the objective of bringing facility and energy managers together from multiple California campus systems to examine best-practice examples of lighting energy efficiency, and discuss planning strategies and methods to reduce lighting energy use.

In recent years, the UC, CSU, and CCC campuses have made great strides in sustainability efforts and have focused a great deal of attention on energy-efficient retrofits for existing buildings. Recently, the lighting industry has seen rapid growth in energy-efficient technology, making lighting a prime candidate for energy-saving retrofits. With the development of lighting systems and controls, however, choosing the proper lighting solutions has become increasingly more complex. The forum focused on providing campus planners with the necessary tools to implement these new technologies to start reducing lighting energy use now by up to 50%.

To reduce travel costs and environmental impacts, CLTC partnered with UC Irvine to provide two dates and two venues for the event. The first conference was held at the UC Davis Activities and Recreation Center on July 1, 2009, and the second at the UC Irvine Student Center on July 13, 2009. The content and format was the same at both sites.

In our current economic environment, reducing energy use is a topic that affects all of California's campuses. This forum is a good example of collaboration to discuss efficiency strategies across campuses and across campus systems. There was no entrance fee for forum attendees.

### 4.5.3 ADVANCED LIGHTING GUIDELINES

CLTC is nearing completion of the daylighting chapter for the New Buildings Institute's *Advanced Lighting Guidelines*, a comprehensive guide to energy-efficient lighting design and integration with other green building practices. This wide-ranging chapter covers the benefits and challenges associated with daylighting, the sources and strategies involved with the practice, and details on fenestration technologies and electric lighting integration. Though the content is highly technical, the chapter is being written in a way that makes the information accessible and understandable to a broad audience, from laypersons to lighting-technology experts.

### 4.5.4 LIGHTING LECTURESHIP PROGRAM

In 2009, the committee for the Don Aumann Memorial Lecture requested nominations for potential speakers at this annual event hosted at UC Davis. Speaker nominations could include leading researchers, advocates, and design professionals that have demonstrated outstanding leadership and accomplishment in lighting and energy efficiency. Excellent candidates were submitted, varying from Dian

Gruenich, Commissioner of the CPUC, to Chip Israel, lighting designer. The Don Aumann lectureship fund, provided by PG&E, will cover expenses for these individuals to travel to UC Davis for the event. The date of the lecture is flexible and will be determined by nominee availability. The first lecture is scheduled to take place in 2010 at a lecture hall on campus. Attendance goals are set at 150. A reception will follow the lecture, and will be planned in part by the UC Davis student chapter of the American Society of Interior Designers. This lecture represents an opportunity to bring the lighting, energy-efficiency, and student communities together for a common topic. Funding to support the planning and logistics of the events is included in the Interagency Agreement.

# APPENDIX A – PIER TECHNOLOGY ROADMAP

## COMMERCIAL DUAL-LOOP LIGHTING CONTROLS FOR SKYLIGHT APPLICATIONS

The 2008 version of Non-Residential Title 24 Standards requires use of skylights in commercial building spaces larger than 8,000 square feet. This includes most big-box retailers, warehouses, and office buildings in California. Reliable, cost-effective control of electric lighting based on available daylight is critical for this measure's success. Current sensors and control technologies do not provide reliable, sustained operation in cost-effective ways.

CLTC has developed laboratory prototypes of a new electric lighting control system for daylight harvesting in skylight applications. The new system has increased reliability and decreased cost through two uniquely purposed photo sensors that offer automatic, continuous monitoring for indoor daylight levels.

The CLTC laboratory prototype, currently being field tested in the West Sacramento Wal-Mart store, has demonstrated very successful performance. This task will focus on bringing this new technology to the market through the development of commercial products, in collaboration with manufacturing partners such as Watt Stopper / Legrand, test bed participants such as Wal-Mart, and California utilities such as PG&E and SMUD.

**Milestones**

- Work with manufacturing partners to develop commercial prototypes of the dual loop photosensing control technology for field-testing in big box retail stores to validate the approach and algorithms.
- Work with manufacturing partners, test bed participants, and utility partners to install commercial prototypes and monitoring equipment in the field in order to validate concepts.
- Monitor the operation of the commercial prototypes by collecting data on electric lighting output, and overall light levels to evaluate energy, luminous performance, and end-user satisfaction.
- Based on these results, develop specifications for commercial products in collaboration with manufacturing.
- Within the framework of the market connection activities, bring the products developed to market consistent with achievement of project task goals.
- Perform project-level technology-transfer.
- Perform project-level production-readiness plan activities.
- Prepare a report describing all task activities and findings, including final specifications of technology and results from laboratory, field testing, and cost effectiveness.

**Deliverables**

- 1-2 page memorandum as to field-test ready prototypes.
- 1-2 page memorandum as to installation of commercial prototypes in the field
- 1-2 page memorandum as to documentation of monitored performance
- 1-2 page memorandum for review as to commercial product specification
- Revised specification as per review
- Project-level Market Connections Deliverables
- Project-level Technology Transfer Deliverables
- Project-level Production Readiness Plan Deliverables
- Final Report

# SMART WINDOWS & SKYLIGHTS

This project will develop a next-generation prototype of automated, operable (AKA “Smart”) windows and skylights in collaboration with manufacturing and utility partners. The smart window and skylight systems will include multiple interior and exterior sensors (e.g., for temperature, occupancy, light, humidity, etc.) and integrated electronics that execute algorithms to maximize energy efficiency as well as comfort through smart operation of the operable fenestration system.

A key element of the proposed Smart Windows and Skylights is the integration of occupancy sensing, which allows for very different operation during occupied and unoccupied times. Just as occupancy sensors are used to turn off electric lights when no one is in the space, they can be used to adjust operable fenestration systems to minimize heat losses or gains depending on interior and exterior conditions and integrated with the other building systems, sensors and rule trees.

The operable elements will include shading systems such as venetian blinds, screens for control of solar heat gain and glare, and ventilation systems such as vents or fans used for natural ventilation and cooling. The sensors will include occupancy/vacancy sensors, photo sensors for interior and exterior light levels, air temperature sensors for interior and exterior temperature levels, humidity sensors for interior and exterior humidity, and radiant temperature sensors for solar heat gain.

For the purposes of the proposed prototype, the controller will be implemented using a computer that executes the control algorithms. Commercial versions will have the algorithms encoded in micro-controllers that are integrated in the fenestration system. The control logic will mimic what smart humans would do, if they were continuously monitoring sensor input.

**Milestones**

- Design and build smart windows and skylights, which will include shading, vents, fans, light and temperature sensors, all connected to a computer that receive sensor signals and sends operation commands for lighting, shading, and ventilation and summarize task results in a memorandum on task activity and lessons learned.
- Design and build two chambers, one on each side of the smart windows and skylights prototype, which will include light sources and heat lamps to control light levels and temperatures in each chamber. A high intensity light source will be used to simulate direct solar radiation in the exterior chamber. A switch will be used to simulate occupancy in the interior chamber and summarize task results in a memorandum on task activity and lessons learned.
- Develop control algorithms for the automatic operation of the Smart Windows and Skylights system and summarize task results in a memorandum on task activity and lessons learned
- Demonstrate the Smart Windows and Skylights to window and skylight manufacturers and form partnerships for the development of commercial products and summarize task results in a memorandum on task activity and lessons learned.
- Estimate energy savings from operation of smart fenestration systems considering various California climates and occupancy scenario and summarize task results in a memorandum on task activity and lessons learned.
- Assist manufacturing partners to develop commercial Smart Windows and Skylight prototypes and summarize task results in a memorandum on task activity and lessons learned.
- Work with California utilities to test and evaluate the commercial prototypes in the field towards verification of energy savings and refinement of controls and control algorithms.
- Perform project-level market connections activities.
- Perform project-level technology transfer activities.
- Perform project-level production readiness activities.
- Prepare a report describing all task activities and findings, including final specifications of technology and results from laboratory and field testing and cost effectiveness.

**Deliverables**

- 1-2 page memorandum as to laboratory prototype

- 1-2 page memorandum as to laboratory testing environment
- 1-2 page memorandum as to control algorithms
- 1-2 page memorandum as to demonstration of smart fenestration operation
- 1-2 page memorandum as to estimation of energy savings
- 1-2 page memorandum as to commercial prototypes
- 1-2 page memorandum as to installation of commercial prototypes in the field
- Project-level market connections
- Project-level technology transfer activities
- Project-level production readiness activities
- Final Report

## DUAL PHOTOSENSOR CONTROLS FOR SIDE-DAYLIGHTING APPLICATIONS

This objective of this project is to develop dual photo sensor control systems for side-daylighting applications. Dual photo sensor controls for electric lighting in daylit spaces show significant promise for increased reliability and cost-effectiveness. CLTC has developed a dual-loop control system specifically for skylight applications, and believes this technology can transfer to side-daylighting applications.

Implementation in skylight applications is relatively easier than in side-daylighting applications, mainly because the two sensors can be part of a single unit placed under a skylight. In side-daylighting applications the two sensors may be in separate locations and their signal may be affected with window and shading system operation. Moreover, a single outdoor sensor can serve as one of the two sensors for all daylit spaces, greatly reducing the overall cost of dual sensor controls for daylighting, while a side-daylight application may require multiple exterior sensors based on the building orientation.

**Milestones**

- Design dual-sensors for side-daylit spaces, which will include consideration of alternative sensor positions, view directions, and angular sensitivities and summarize task results in a memorandum on task activity and lessons learned.
- Develop laboratory prototypes of the most promising designs
- Test the laboratory prototypes to ensure proper operation
- Work with manufacturing partners to develop viable commercial versions of the technology suitable for field testing and evaluation.
- Work with manufacturing and utility partners install commercial prototypes and conduct field tests.
- Based on the results from the previous activity, develop specifications for commercial products after consultations manufacturing partners.
- Perform program-wide market connection activities.
- Perform project-level technology transfer activities.
- Perform project-level production readiness activities.
- Prepare a report describing all task activities and findings, including final specifications of technology and results from laboratory, field testing and cost effectiveness.

**Deliverables**

- 1-2 page memorandum as to dual sensor alternative designs
- 1-2 page memorandum as to laboratory prototypes
- 1-2 page memorandum as to test laboratory prototypes
- 1-2 page memorandum as to commercial prototypes
- 1-2 page memorandum as to testing of commercial prototypes
- 1-2 page memorandum for review as to commercial product specification
- Revised specification as per review
- Project-level market connections
- Project-level technology transfer activities

- Project-level production readiness activities
- Final report

## DAYLIGHT OPTIMIZATION FOR SKYLIGHT APPLICATIONS

One of the most common problems in skylight applications is glare due to high luminance ratios between bright skylight glazing and relatively darker ceiling or interior roof surfaces. Moreover, excessive daylight contributes to increased solar heat gain, compromising the electric lighting savings.

CLTC will collaborate with commercial, manufacturing and utility partners to develop technologies that reducing the glare from skylights by filtering and redirecting a fraction of the incoming daylight towards the ceiling, as well as technologies that automatically adjust the transmission of skylights, modulating the incoming daylight to control incoming daylight and associated solar heat gain. This technology will be incorporated into the structure and design of next generation skylights rather than being add-on devices.

**Milestones**

- Work with test bed partners such to select test bed participants and other commercial spaces with skylights for testing and evaluation of new technologies.
- Work with test bed partners and utilities to measure and evaluate the luminous and energy performance of the existing skylights in the selected test sites and summarize task results in a memorandum on task activity and lessons learned.
- Work with manufacturing partners to develop fixed technologies involving optics within or below the skylight well that redirect some of the incoming daylight to illuminate the ceiling area so as to reduce contrast and associated glare and summarize task results in a memorandum on task activity and lessons learned.
- Work with manufacturing partners to develop operable technologies that automatically modulate the incoming daylight to reduce excessive daylight (non-shadowing methods) and associated solar heat gains.
- Work with manufacturing partners to develop commercial prototypes of developed technologies.
- Work with manufacturing and utility partners to install the new technologies in the selected sites for testing and evaluation.
- Measure and evaluate the performance of the new technologies with respect to daylight levels and glare, as well as increased energy savings through automatic modulation of skylight transmittance.
- Based on the results of the automated operable technologies, estimate energy savings and cost effectiveness and summarize results.
- Program-wide market connection activities.
- Perform technology-transfer activities with the preparation and implementation of the program-level market connection activities.
- Perform project-level production readiness plan activities.
- Prepare a report describing all activities and findings, including final specifications of technology and results from laboratory and field testing and cost effectiveness.

**Deliverables**

- 1-2 page memorandum as to selection of testing sites
- 1-2 page memorandum as to performance of existing skylights
- 1-2 page memorandum as to glare-reducing technologies
- 1-2 page memorandum as to operable daylight modulation technologies
- 1-2 page memorandum as to commercial prototypes
- 1-2 page memorandum as to Installation of new technologies in the field
- 1-2 page memorandum as to performance of operable systems
- 1-2 page memorandum as to energy savings and cost-effectiveness of daylight modulation technologies.
- Project-level market connections deliverables
- Project-level technology transfer deliverables

- Project-level production readiness deliverables
- Final report

## SOLAR CANOPY FOR CORE DAYLIGHTING

Researchers at the University of British Columbia (UBC) have developed “Solar Canopy”, a combination of moveable and fixed mirrors with a horizontal light-pipe that redirects and distributes direct sunlight into the core of multistory buildings. The light pipe is integrated with fluorescent lighting, which is automatically dimmed based on available sunlight. Solar Canopy is currently being demonstrated at a UBC campus building in Vancouver, B.C.

This kind of system is feasible today because of the relatively recent availability of films with very high reflectance that line the light distribution channel. The particular solution that the researchers at UBC developed has a very efficient system for distributing light throughout the building. Potential benefits include reduction in use of electric lighting, both overall and during periods of peak electricity usage, and better psychological connection of occupants to exterior conditions.

CLTC will collaborate with UBC, manufacturing partners such as 3M, and test bed participants such as UC Davis to test the feasibility of this system for the mid-Central Valley latitude and climate, by installing it at a building at UCD and monitoring its performance for a period of time long enough to allow for estimation of annual performance on comfort, energy and peak electricity demand.

**Milestones**

- Collaborate with UBC and UCD to install the Solar Canopy system at an appropriate testing site at UCD and ensure proper operation.
- Instrument the test site to allow collection of vital data.
- Develop testing protocols in collaboration with UBC, and monitor performance over a solstice-to-solstice period to enable evaluation of annual performance, including an equinox and the summer and winter solstices, so as to understand the system’s performance vs. the ecliptic.
- Analyze the monitored performance data and use them with mathematical models for estimation of annual energy savings and peak demand reduction.
- Evaluate the cost effectiveness of Solar Canopy based on the annual performance evaluation and the potential for reduced product and installation costs through commercial production.
- Based on the results from the previous activity, develop specifications for commercial products in collaboration with manufacturing partners.
- Program-wide market connection activities.
- Perform technology-transfer activities with the preparation and implementation of the program-level market connection activities.
- Perform project-level production readiness plan activities.
- Prepare a report describing all activities and findings, including final specifications of technology and results from laboratory and field testing and cost effectiveness.

**Deliverables**

- 1-2 page memorandum as to Installation at UCD campus building
- 1-2 page memorandum as to test site instrumentation
- 1-2 page memorandum as to testing protocols and performance monitoring
- 1-2 page memorandum as to performance evaluation
- 1-2 page memorandum to cost-effectiveness
- 1-2 page memorandum for review as to commercial product specification
- Revised specification per review
- Project-level market connections deliverables
- Project-level technology transfer deliverables
- Project-level production readiness deliverables
- Final Report

# DEVELOP EXTERIOR LIGHTING TECHNOLOGIES - HIGH-EFFICIENCY BI-LEVEL SMART WALL PACKS

Most commercial and industrial buildings have exterior wall-mounted fixtures used for common areas and security lighting, which operate for extended hours. The most common light sources in theses fixtures are high-pressure sodium and mercury vapor lamps, both have poor color rendering and little or no controllability. Typical optical systems simply spray the light sideways and upwards, creating more light pollution and glare than effective illumination. CLTC demonstrated optical controls on wall packs using conventional light sources as part of PIER research in the 2002-2005 program. LEDs and induction lamps can offer greater efficiency, color rendering and controllability, both optically and in combination with occupancy and photo sensors.

CLTC will work with manufacturing partners to develop new LED wall-packs with integrated optics and. These luminaires will direct light where needed and provide occupancy-based bi-level control. These strategies maximize energy savings. Luminaire demonstrations will be conducted with partners outlined in Appendix B – Demonstration Roadmap.

**Milestones**

- Work with test bed partners to identify and select representative test sites for testing and evaluation of new technologies.
- Measure the performance of the existing wall packs with respect to hours of operation, energy requirements, and light distribution.
- Work with manufacturing partners to develop enhanced LED and induction luminaires with optical controls that distribute light where needed, greatly reducing energy requirements and light pollution. The new luminaires will include occupancy, daylight, and DR controls.
- Develop suitable control systems for the new luminaires and modifications of ballasts and drivers to institute bi-level control and summarize task results.
- Construct laboratory prototypes with integrated controls that will be usable for field evaluations.
- Measure and evaluate the performance of the new luminaires with respect to energy requirements, light distribution, and controls operation.
- Based on the results from the previous activity, develop specifications for commercial products after consultations manufacturing partners.
- Perform program-wide market connections activities.
- Perform project-level technology transfer activities.
- Perform project-level production readiness activities.
- Prepare a report describing all activities and findings, including final specifications of technology, results from laboratory, field testing and cost effectiveness when compared to conventional technology.

**Deliverables**

- 1-2 page memorandum regarding test locations
- 1-2 page memorandum regarding existing lighting performance
- 1-2 page memorandum regarding new LED/luminaires
- 1-2 page memorandum as to new control systems
- 1-2 page memorandum as to lab prototypes
- 1-2 page memorandum as to new luminaires in test locations
- 1-2 page memorandum as to performance evaluation
- 1-2 page memorandum for review as to commercial product specification
- Revised specification per review
- Project-level market connections deliverables
- Project-level technology transfer deliverables
- Project-level production readiness deliverables
- Final Report

# LED / INDUCTION LONGEVITY IN EXTERIOR APPLICATIONS

Both LEDs and induction lamps promise longevity far beyond that of conventional discharge lamps. In many cases, the financial viability of such fixtures is based on long life and low maintenance. With these new technologies, manufacturers are offering luminaires with a service life of up to 25 years. If insects penetrate the housing, hatch and die there, the light output may be reduced. If birds defecate or nest on top of LED heat sinks, the thermal performance will certainly be compromised. Existing UL standards evaluate polymers for flammability, dielectric and structure, not for optical properties through 25 years of UV exposure in places like Southern California.

CLTC will collaborate with manufacturing partners such as Beta Lighting, Full Spectrum Solutions and California utilities such as SCE, to evaluate the ability of current range of exterior induction and LED luminaires to sustain light output after extended exposure to ozone, insects, dirt, extended high levels of UV radiation and bird nests.

**Milestones**

- Work with manufacturing and utility partners to test fixtures through prolonged UV exposure that would be expected over anticipated life in various climates.
- Work with manufacturing and utility partners to test fixtures exposed to insect populations such as those that would be expected over the projected life of the fixture. Measurements will be focused on evaluating the thermal and optical consequences of insect infiltration, which will then be projected over the effective lamp life to estimate effects over time. The UC Davis Entomology Department will advise on the type and make-up of insect populations throughout California's.
- Work with manufacturing partners to test the effect of dirt, pollutants, environmental moisture, salt air and particulate matter (i.e. soot, tire dust), debris, and nesting materials on optical and thermal properties, which will be used with quality engineering standards to determine effective life projections of light output and probability for failure of electronics and LED and induction lamp degradation due to increased stress or optical deterioration.
- Based on the results from the previous activity develop specifications for commercial products in collaboration with manufacturing partners.
- Perform program-wide market connections activities.
- Perform project-level technology transfer activities.
- Perform project-level production readiness activities.
- Prepare a report describing all activities and findings, including final specifications of technology, results from laboratory, field testing and cost effectiveness when compared to conventional technology

**Deliverables**

- 1-2 page memorandum as to UV effects testing protocol and setup, UV effects results
- 1-2 page memorandum as to Insect effects testing protocol and setup, Insect effects results
- 1-2 page memorandum as to dirt, debris and nesting effects testing protocol and setup, dirt, debris and nesting effects results
- 1-2 page memorandum for review as to commercial product specification
- Revised specification per review
- Project-level market connections deliverables
- Project-level technology transfer deliverables
- Project-level production readiness deliverables
- Final Report

## SMART EXTERIOR DARK-SKY FRIENDLY, HISTORICALLY-ACCURATE LIGHTING

Many California communities have exterior luminaires that fit within the cultural design contexts of their downtowns or historic neighborhoods. These fixtures are typically highly inefficient and a large portion of their delivered flux is directed skyward. Typical light source for these luminaires are high-pressure sodium lamps, which have poor color rendering capabilities and relatively short life.

CLTC will collaborate with manufacturing partners to develop new LED exterior luminaires that maintain the overall appearance of historic luminaires, but utilize advanced optics and adaptive controls to improve energy efficiency and reduce light pollution.

**Milestones**

- In collaboration with test bed participants, survey existing decorative historical luminaires and select fixtures and sites for the development and testing of the new luminaires.
- Measure and evaluate the performance of existing historical fixtures with respect to energy and light distributions.
- Work with manufacturing partners such to design alternate configurations and optics for the historical fixtures that will provide the desired candlepower distributions (deliver maximal flux with minimal glare).
- Work with manufacturing partners to design alternate controls that will provide occupancy sensing level control, daylight sensing dimming, and demand response capability.
- Work with manufacturing partners to produce luminaire prototypes of the new designs for testing and evaluation in the field.
- Work with test bed participants to install and field test luminaires in conjunction with activities outlined in Appendix B – Demonstration Roadmap.
- Measure and evaluate the performance of the new fixtures with respect to energy requirements, light distribution and output, community acceptability and compare it with the performance of the original fixtures.
- Develop specifications for commercial products in collaboration with manufacturing partners.
- Perform program-wide market connections activities.
- Perform project-level technology transfer activities.
- Perform project-level production readiness activities

**Deliverables**

- 1-2 page memorandum as to selection of testing sites and fixtures
- 1-2 page memorandum as to evaluation of existing fixtures
- 1-2 page memorandum as to designs of new optics
- 1-2 page memorandum as to design of new controls
- 1-2 page memorandum as to prototypes of new LED fixtures
- 1-2 page memorandum as to installation of new LED fixtures in test sites
- 1-2 page memorandum as to evaluation of new LED fixtures
- 1-2 page memorandum for review as to commercial product specification
- Revised specification per review
- Project-level market connections deliverables
- Project-level technology transfer deliverables
- Project-level production readiness deliverables
- Final Report

## SIDE PROJECTING LEDS WITH PV POWER AND CONTROL

Typically, new municipal, freeway, and airport signage requires that large trenches be dug for high voltage electrical supply and/or control wires required by the signs. When this heavy wiring is required on roadways, ramps, taxiway, and runways, significant costs are borne by the agency involved, coupled with

high risk to the installation crews and travelers. Typical fixtures are relatively short-lived and sign lighting maintenance carries risks similar to installation. CLTC believes significant advances in LEDs, photovoltaic arrays, wireless controls, and batteries have been made to create sign lighting that is grid-connected through direct burial DC circuits. These circuits could be installed in slit trenches and dependable enough for critical applications in transportation.

**Milestones**

- In collaboration with the manufacturing and university partners, design new sign lighters using high-power, high-efficacy LEDs and arrays of optics to direct the light in extremely targeted patterns that do not create visual pollution or distracting glare.
- In collaboration with the manufacturing partners, design, identify and test photovoltaic arrays with efficiency adequate to provide power even on days with inclement weather.
- In collaboration with the manufacturing partners, identify and test polymer lithium ion storage battery arrays.
- In collaboration with the manufacturing partners, create radio frequency control systems that preserve and extend battery life and status reporting systems.
- In collaboration with the task partners, test and evaluate the new luminaires in the laboratory and in the field towards final specifications for commercial products.
- Work with industry partners to develop commercial prototypes for testing in real world applications.
- Work with industry and utility partners, test bed participants such as roadway system managers such as federal property managers, education campus managers, CalTrans, and airport managers/Federal Aviation Authority to install commercial prototypes in the field for demonstration and evaluation. The installation will include monitoring equipment for energy and luminous distributions. These tests will be conducted at selected roadways, small airports, and/or military facilities. Summarize task results in a memorandum on task activity and lessons learned
- Monitor and evaluate the performance of the commercial prototypes in the field with respect to energy requirements, light distribution and output, and acceptability to the organization. Summarize task results in a memorandum on task activity and lessons learned.
- Develop specifications for commercial products in collaboration with manufacturing partners and summarize task results in a memorandum on task activity and lessons learned
- Within the framework of the Program-wide Market Connections, bring the products developed to market consistent with achievement of project task goals.
- Perform program-wide market connections activities.
- Perform project-level technology transfer activities.
- Perform project-level production readiness activities

**Deliverables**

- 1-2 page memorandum as to luminaires design
- 1-2 page memorandum as to PV Array design
- 1-2 page memorandum as to Battery Arrays design
- 1-2 page memorandum as to control system design
- 1-2 page memorandum as to laboratory prototypes
- 1-2 page memorandum as to commercial prototypes
- 1-2 page memorandum as to installation of commercial prototypes in the field
- 1-2 page memorandum as to monitoring and evaluation of field performance
- 1-2 page memorandum for review as to commercial product specification
- Revised specification per review
- Project-level market connections deliverables
- Project-level technology transfer deliverables
- Project-level production readiness deliverables
- Final Report

# DEVELOP INTERIOR LIGHTING TECHNOLOGIES/RETROFIT LED DOWNLIGHTS

This task will focus on developing new LED downlight fixtures that offer improved visual comfort and include occupancy and demand response controls.Downlights are among the most used fixtures in residential applications and are increasingly used in commercial applications. In prior work CLTC has demonstrated a method to reduce glare and simplify wiring and installation complexity with improved thermal performance of new fixtures. The resultant fixtures are very promising but fall short in two areas: they still have high local brightness and are expensive. Generally, the LED heat sinks give off too much heat and make it unfeasible for recessed cans.

The proposed project will focus on providing a second path of light to the ceiling area surrounding each fixture, which will reduce the contrast and resulting glare. The second part of the effort involves consumer cost reduction strategies. CLTC will examine techniques for using many low cost, high efficacy emitters to achieve high efficiency and reduced overall costs. There is also an excellent potential of using existing wiring and fixture bodies with innovative control systems to retrofit the far larger population of existing recessed downlights. This project aims to further refine this kind of product and to make it available for the far larger constellation of retrofit applications.

**Milestones**

- Modify and calibrate its existing swing-arm goniophotometer
- Design new downlight fixtures that use multiple arrays of low-cost high efficacy LEDs and direct some of the light towards the surrounding ceiling area.
- Test and evaluate the new luminaires in the laboratory and in the field towards final specifications for commercial products and summarize task results in a memorandum on task activity and lessons learned
- Develop commercial prototypes of systems for testing in real world applications and summarize task results in a memorandum on task activity and lessons learned.
- Work with industry and utility partners to install commercial prototypes in field for demonstration and evaluation. The installation will include monitoring equipment for energy and luminous distributions.
- Monitor and evaluate the field performance of the commercial prototypes in the field with respect to energy requirements, light distribution and glare reduction, towards final specifications for commercial products. Summarize task results in a memorandum on task activity and lessons learned.
- Develop specifications for commercial in collaboration with manufacturing partners.
- Within the framework of the Program-wide Market Connections, bring the products developed to market consistent with achievement of project task goals.
- Perform program-wide market connections activities.
- Perform project-level technology transfer activities.
- Perform project-level production readiness activities

**Deliverable:**

- 1-2 page memorandum as to modified goniophotometer
- 1-2 page memorandum as to laboratory LED (luminaires) prototypes
- 1-2 page memorandum as to fixture evaluation
- 1-2 page memorandum as to commercial prototypes
- 1-2 page memorandum as to performance of commercial prototype performance.
- 1-2 page memorandum for review as to commercial product specification
- Revised specification per review
- Project-level market connections deliverables
- Project-level technology transfer deliverables
- Project-level production readiness deliverables
- Final Report

# DIGITAL OPEN SOURCE LIGHTING CONTROLS COMMISSIONING TOOL

As digital technology is becoming the standard in lighting controls, the National Electrical Manufacturers Association (NEMA) has developed a new digital lighting controls open protocol (available without charge or license to all manufacturers and all users, i.e. “open source”), referred to as NEMA 243. This new protocol is based on DALI (Digital Addressable Lighting Interface), extending it to support more than ballasts, i.e., sensors, switches and controllers.

CLTC has been working with NEMA on debugging, testing and demonstrating NEMA 243 in two installations: one at CLTC and the other in two UC Davis campus classrooms. Both installations show promise for significant energy savings through tuning of luminaries output and implementation of scenes (preset light levels for one or more fixtures within a given space) and smart operation (appropriate response to environmental conditions within a controlled space) based on sensors and control algorithms.

While installation of digital controls is very simple, as all components (ballasts, controllers, switches, sensors, etc.) are linked in a linear way, commissioning can be pretty challenging. Commissioning involves grouping of luminaires and development of control algorithms by allowing specification of control algorithms based on the values of sensor signals and the state of the lighting systems components.

Pursuant to Contract UC MR-022, CLTC is working on the development of digital lighting controls technology which will be completed in spring 2011. This project is focused on the development of the actual commissioning tool in collaboration with NEMA lighting controls manufacturers.

**Milestones**

- Develop specifications for a commissioning tool at the end of the current project with NEMA and Energy Commission, to allow interaction and setup of digital lighting control systems by installers, commissioning agents and building users and summarize task results in a memorandum on task activity and lessons learned.
- Determine the component parts of the program and develop a list of modules required to bring the data into the tools and summarize task results in a memorandum on task activity and lessons learned.
- Create computer code of commissioning software which includes user-friendly interface (alpha version) and data verification and summarize task results in a memorandum on task activity and lessons learned.
- Assure that alpha version of commissioning software is distributed to the controls vendors for their evaluation and input and summarize task results in a memorandum on task activity and lessons learned.
- Resolve problems and issues. Refine the product. Produce a more final version (beta version) and summarize task results in a memorandum on task activity and lessons learned.
- Distribute the beta version to the manufactures that will review and test it and summarize task results in a memorandum on task activity and lessons learned.
- Complete the needed modifications and offer source code to NEMA for free distribution to the industry and submission to CIE as a world standard and summarize task results in a memorandum on task activity and lessons learned.
- Within the framework of the Program-wide Market Connections, bring the products developed to market consistent with achievement of project task goals.
- Perform program-wide market connections activities.
- Perform project-level technology transfer activities.
- Perform project-level production readiness activities

**Deliverables**

- 1-2 page memorandum as to commissioning tool requirements
- 1-2 page memorandum as to developed list of needed software modules

- 1-2 page memorandum as to Alpha version of the commissioning software
- 1-2 page memorandum as to distribution of alpha version and evaluation protocol
- 1-2 page memorandum as to Beta version of the commissioning software
- 1-2 page memorandum as to distribution of Beta version of software
- 1-2 page memorandum as to Final Version of Commissioning Software
- 1-2 page memorandum for review as to commercial product specification
- Revised specification per review
- Project-level market connections deliverables
- Project-level technology transfer deliverables
- Project-level production readiness deliverables
- Final Report

## WALL WASH FOR TASK-AMBIENT DEMAND RESPONSIVE AMBIENT LIGHTING

The benefits of task/ambient lighting have been demonstrated in a number of PIER research projects and demonstrations. However, office spaces that rely on task lighting have an unfortunate side effect known as “cave effect”. The low levels of ambient light and the carefully controlled light on work surfaces leave little available illumination on vertical surfaces. This causes a feeling of a dark and dismal environment for the occupants.

CLTC will collaborate with manufacturing partners such as Finelite, Samsung and PG&E to develop strategies and technologies that direct ambient light on walls and vertical surfaces to minimize the cave effect and contribute to widespread use of task-ambient approaches. Focusing ambient lighting on vertical surfaces has the potential to decrease overall ambient lighting energy requirements.

Hallways, corridors and other non-task and walk-off building areas are among the least visually critical areas and thus best targets for demand response reductions. There is a distinct need to create demand responsive controls for these lighting applications.

The “Office of the Future” project, a multi-utility initiative led by the Design and Engineering Services office of SCE, has determined the requirements for the office environment as we meet targets for 25% and 50% energy reductions and finally achieving net zero energy design. Control and duty cycling of peripheral loads looks like a key component of future strategies. This must be combined with occupant comfort to maintain productivity. Many studies show that the typical office space is occupied only half the time during the work day. Occupancy sensitive control of task lights, monitors and other plug loads is key.

CLTC will work with manufacturers such as Finelite, Elliptipar, Watt Stopper/Legrand, and test bed partners like PG&E, SCE, SMUD and DGS to develop a wall-washing luminaire system with controls that adjust lighting based on demand response signals from utilities, which can also be exploited for cycling of plug loads, such a personal space heaters, simultaneously reducing their demand in response to the same DR signal.

**Milestones**

- Work with test bed partners such as DGS, PG&E, SCE, SMUD and manufacturers such as Finelite for identification and selection of appropriate test locations in office buildings and summarize task results in a memorandum on task activity and lessons learned.
- Work with test bed partners such as DGS to measure the energy requirements of the existing lighting systems in the test locations.
- Measure the performance of existing systems with respect to energy requirements and luminous comfort, especially luminance ratios for evaluation of cave effect and summarize task results in a memorandum on task activity and lessons learned.
- Work with manufacturers such as Elliptipar, Finelite and Samsung to develop new luminaires that direct ambient lighting to vertical surfaces to reduce cave effects and improve overall light distribution.

The new luminaires will seamlessly interoperate with the balance of Task and ambient lighting in the office environment and summarize task results in a memorandum on task activity and lessons learned.
- Work with manufacturers such as Finelite and Watt Stopper/Legrande to develop luminaires with demand response (DR) controls for testing and evaluation at the test locations and summarize task results in a memorandum on task activity and lessons learned.
- Work with manufacturers such as Elliptipar, Finelite, Samsung, Watt Stopper/Legrand and test bed partners like PG&E to install new luminaires and controls where applicable in the selected test sites and summarize task results in a memorandum on task activity and lessons learned.
- Test, collect and evaluate the DR performance data of the new luminaires and their controls with respect to load reduction and occupant acceptance with respect to energy requirements and luminous comfort and summarize task results in a memorandum on task activity and lessons learned.
- Based on the results from the previous activity in Task 2.12 develop specifications for commercial products after consultations with the PAC as outlined in Task 1.10 and in collaboration with manufacturing partners and summarize task results in a memorandum on task activity and lessons learned.
- Develop a specification for guidance of commercial practice so that the “Cave-Effect” will no longer be a deterrent to the adoption of Task/ambient strategies and summarize task results in a memorandum on task activity and lessons learned.
- Within the framework of the Program-wide Market Connections, bring the products developed to market consistent with achievement of project task goals.
- Perform program-wide market connections activities.
- Perform project-level technology transfer activities.
- Perform project-level production readiness activities

**Deliverables**
- 1-2 page memorandum as to test locations existing lighting performance
- 1-2 page memorandum as to measurement of performance of existing systems
- 1-2 page memorandum as to development of vertical illumination strategies
- 1-2 page memorandum as to new luminaires with DR controls New Wallwash Fixtures
- 1-2 page memorandum as to installation of new luminaires in test locations
- 1-2 page memorandum as to measurement and evaluation
- 1-2 page memorandum for review as to commercial product specification
- Revised specification per review
- Project-level market connections deliverables
- Project-level technology transfer deliverables
- Project-level production readiness deliverables
- Final Report

## SOLID STATE LUMINAIRES FOR HIGH BAY, POLES, AND OFFICE APPLICATIONS

Plasma light sources were originally developed for video equipment such as projectors and television sets. They operate on physical principles similar to those used in high-intensity discharge (HID) lamps, the most significant differences being 1) the gas in the capsule is excited magnetically instead of by a high-intensity electric discharge and 2) the device is miniaturized, the light-emitting capsule being approximately half the size of a jelly bean.
Plasma light sources have strong potential for higher efficacy than linear fluorescent lamps, with better color rendition and longer life. They are also dimmable. As very-nearly point sources, plasma lights can be used effectively with optical materials to provide desired candlepower distributions. They have the potential to change the paradigm of ceiling light fixtures that occupy a large fraction of the ceiling real estate, because a single plasma source the size of a few cubic inches can replace multiple fluorescent fixtures in office spaces. This implies significant reduction in materials, transportation, storage and maintenance costs. Adding controllability and light quality with high color rendering and efficacy makes

plasma sources very attractive from energy, comfort, sustainability and cost points of view for office, pole and high bay lighting.

CLTC will collaborate with manufacturing partners such as Luxim, SCE and PG&E and SMUD to develop plasma luminaires for test bed participants such as athletic venues, warehouses, street lighting and open office applications, focusing on the design of optics for direct, indirect and direct/indirect approaches that will provide uniform illumination throughout open space areas without glare and shadows. Prototypes will be developed and tested in typical recreational athletics venues, warehouses, street lighting and office settings and compared with current lighting options with respect to illuminance and luminance distributions, luminaire efficacy and efficiency, energy requirements and economics.

**Milestones**

- Collaborate with manufacturing partners such as Luxim to design and fabricate prototype luminaires for direct, indirect and direct/indirect illumination in sports venues, warehouses, street lighting and open office spaces. The development will include initially computer-aided design of optics to produce desired candlepower distributions for direct and indirect lighting approaches and then iteration of fabrication of prototypes and refinement of the most promising designs approaches and summarize task results in a memorandum on task activity and lessons learned.
- Work with manufacturing partners such as Luxim, SCE, SMUD and PG&E to identify and select appropriate test sites for the new luminaires. The spaces will be selected based on designs that will be selected for field testing and summarize task results in a memorandum on task activity and lessons learned.
- Work with test bed partners such as SCE, SMUD and PG&E to install plasma prototype luminaires in the selected test sites and measure and evaluate their performance (e.g., energy consumption, light distribution) and summarize task results in a memorandum on task activity and lessons learned.
- Based on the results from the previous activity in Task 2.13develop specifications for commercial products after consultations with the PAC as outlined in Task 1.10 and in collaboration with manufacturing partners and summarize task results in a memorandum on task activity and lessons learned.
- Within the framework of the Program-wide Market Connections, bring the products developed to market consistent with achievement of project task goals.
- Perform program-wide market connections activities.
- Perform project-level technology transfer activities.
- Perform project-level production readiness activities

**Deliverables**

- 1-2 page memorandum as to luminaire designs, laboratory prototypes
- 1-2 page memorandum as to test site selection
- 1-2 page memorandum as to installation of solid-state prototypes in the field
- 1-2 page memorandum for review as to commercial product specification
- Revised specification per review
- Project-level market connections deliverables
- Project-level technology transfer deliverables
- Project-level production readiness deliverables
- Final Report

## OLEDS FOR OFFICE AMBIENT LIGHTING

Organic Light Emitting Diodes (OLEDs) are made up into arrays of devices on luminous panels. While these panels cannot, as yet, provide general illumination they appear to be suitable for ambient illumination. They may well lend themselves to integration in office partition systems where they will be close to the target area so that they may light without being obtrusive.

OLEDs are a new technology that will require a new type of control and new mounting techniques. Their planar nature may allow us to merge them into standard office partitions. It is hoped that their gentle glow will provide the ambient illumination while conventional LED sources will provide specific Task illumination. The combined technologies should provide energy efficient, comfortable lighting for many years without service.

**Milestones**

- Obtain and provision OLED panels for evaluation and summarize task results in a memorandum on task activity and lessons learned.
- Measure luminous and energy performance of existing OLED panels and map light distributions. The performance of the systems will be measured against office lighting requirement and summarize task results in a memorandum on task activity and lessons learned.
- Integrate the OLED panels into prototype office partitions and summarize task results in a memorandum on task activity and lessons learned.
- Work with test bed partners such as DGS to equip office suites with the new systems
- Measure and evaluate the luminous and energy performance of the new luminaires and controls at the test sites (e.g., energy requirements, light distribution and occupant satisfaction). The results of the measurements and associated human factors evaluations will determine if there is potential for this new technology and summarize task results in a memorandum on task activity and lessons learned.
- Within the framework of the Program-wide Market Connections, bring the products developed to market consistent with achievement of project task goals.
- Perform program-wide market connections activities.
- Perform project-level technology transfer activities.
- Perform project-level production readiness activities

**Deliverables**

- 1-2 page memorandum as to OLED panel sourcing
- 1-2 page memorandum as to measurement of OLEDS lighting performance
- 1-2 page memorandum as to office system prototypes
- 1-2 page memorandum as to office prototype with integrated OLED panels
- 1-2 page memorandum as to Installation of systems in DGS facilities
- 1-2 page memorandum as to evaluation of luminaires in test locations
- 1-2 page memorandum for review as to commercial product specification
- Revised specification per review
- Project-level market connections deliverables
- Project-level technology transfer deliverables
- Project-level production readiness deliverables
- Final Report

## NEXT GENERATION LED RESIDENTIAL LIGHTING AND MANUFACTURER TRAINING

LEDs have much to offer as a solution for residential lighting. They have high luminaire and application efficacy, are long-lived and are well-suited for control. Because of their small size and unidirectional output, LED sources offer potential for new form factors, shapes and candlepower distributions. To date, lighting designs have treated LEDs as though they performed just like traditional light sources.

CLTC will work with manufacturing partners such as Intematix, Acuity and SDGE to develop the next generation of LED residential lighting that will greatly reduce energy consumption and will yield extended demand offset together with instantaneous demand response capabilities. Consumers will get better controls and should not have to replace the light source for the duration of their mortgage. These benefits

would add value and make it more probable that consumers would acquire and utilize the more efficient fixtures despite higher costs.

Existing manufacturers of decorative residential lighting fixtures are very capable in the areas of metal bending, glass and finishes and packaging. They need help with new LED technologies that require knowledge and experience with thermodynamics, electronics and optics. CLTC will work with manufacturing partners such as Acuity to develop the next generation of residential LED luminaires.

The target will be decorative LED-based luminaires, which, in addition to light sources and optics, will include occupancy detection and DR controls. Creative ways will be developed to integrate heat sink structures into fixtures with shapes and patterns attractive to consumers. Because this work would target leading US manufacturers of lighting, it is assumed that other manufacturers will seek to emulate the outcomes, speeding the technology from the lab to the marketplace.

**Milestones**

- In collaboration with manufacturing partners such as Intematix and Acuity, design next generation (low cost) LED luminaires for decorative residential lighting, which will include high efficiency LED light sources and advanced occupancy and DR controls. These new luminaires, intended to take advantage of the inherent properties of solid state lighting, will include self-illuminated shades with molded phosphorescent polymers excited by integrated LED sources. The new luminaires will focus on aesthetics, thermal management and candlepower distributions that match residential decorative and low and moderate level Task applications.
- Develop appropriate drivers and controls for the new LED luminaires. The controls components will include occupancy and DR controls for increased energy efficiency and peak demand reduction and summarize task results in a memorandum on task activity and lessons learned.
- Work with the manufacturing partners such as Intematix and Acuity to develop prototypes of new luminaire designs for laboratory and field testing and evaluation. Some fixtures will be modifications of existing designs, others completely novel and summarize task results in a memorandum on task activity and lessons learned.
- Work with test bed partners such as SDGE and other CA utilities to demonstrate and evaluate fixture performance of the prototype luminaires and controls in the field and summarize task results in a memorandum on task activity and lessons learned.
- Based on the results from the previous activity in Task 2.15 develop specifications for commercial products after consultations with the PAC as outlined in Task 1.10 and in collaboration with manufacturing partners and summarize task results in a memorandum on task activity and lessons learned .
- Within the framework of the Program-wide Market Connections, bring the products developed to market consistent with achievement of project task goals.
- Perform program-wide market connections activities.
- Perform project-level technology transfer activities.
- Perform project-level production readiness activities

**Deliverables**

- 1-2 page memorandum as to design of new LED luminaires
- 1-2 page memorandum as to design/sourcing of drivers, occupancy and DR controls
- 1-2 page memorandum as to developing prototypes for testing and evaluation
- 1-2 page memorandum as to Installation new luminaires in the field
- 1-2 page memorandum for review as to commercial product specification
- Revised specification per review
- Project-level market connections deliverables
- Project-level technology transfer deliverables
- Project-level production readiness deliverables
- Final Report

# APPENDIX B – DEMONSTRATION ROADMAP

## DGS LIGHTING PROGRAM

The State of California is one of the largest building owners in the State. DGS operates a broad range of structures for the State of California. They run the gamut from multi-story offices to garages and warehouses. The buildings of DGS are a great place to demonstrate new technologies and conduct tests to validate their performance. The Contractor will also work with DGS to create training programs and manuals to support DGS in their implementation of the Governor Schwarzenegger's Executive Order (Executive Order S-20-04) for the reduction of the state's carbon footprint.

**Milestones**

- Work with manufacturing partners such as Lutron, Universal Devices, Watt Stopper/Legrand, Finelite, and SMUD, PG&E, SDG&E and SCE to demonstrate and evaluate current state-of-the-art technologies in State structures within the utilities' territories (Consult with DGS on Demonstration Lighting Retrofit Programs) and summarize task results in a memorandum on task activity and lessons learned.
- Work with DGS staff to identify buildings for field trials of new and innovative technologies and conduct the field trials using State office buildings, warehouses and parking areas as living laboratories. Summarize task results in a memorandum on demonstration of advanced lighting technologies in DGS buildings.
- Equip separate floors or areas of State structures with different lighting technologies and contrast and compare them with control areas and summarize task results in a memorandum on task activity and lessons learned.
- Prepare a manual detailing efficient lighting practices and strategies for conservation throughout the DGS system and summarize task results in a memorandum on task activity and lessons learned.
- Prepare a report describing all activities and findings, including final specifications of technology with results from laboratory, field testing and cost effectiveness of the technology. Final task report will serve as a standalone appendix to the Final Report for the overall project.

**Deliverables**

- 1-2 page memorandum as to Consultation with DGS on Demonstration Lighting Retrofit Programs
- 1-2 page memorandum as to demonstration of advanced lighting technologies in DGS buildings
- 1-2 page memorandum as to development of manual
- Best Practices Manual for DGS
- Final Report

## MARKET ADOPTION/OUTREACH FOR TECHNOLOGY TRANSFER

The purpose of this task is to inform key audiences about new and emerging lighting and daylighting technologies and help form partnerships for accelerated wide spread acceptance and use. CLTC will engage in outreach activities as a means of technology transfer to key institutions, agencies, and other audiences such as California state agencies, academic institutions and trade organizations.

CLTC will continue to build institutional connections between PIER lighting research and California state agencies and academic institutions in order to expose them to Task 2 outcomes and other PIER lighting technologies, understand specific needs and inform the PIER Lighting R&D process.

Buildings owned by the State of California are key opportunities to demonstrate PIER lighting technologies and learn about the needs of large end-users. The CLTC has cultivated these relationships

over the last three years though the MOU established with the Department of General Services and the PIER technologies demonstration program in UC and CSU campuses.

**Milestones**

- Build institutional connections between PIER research and California State agencies and academic institutions and extend them to include such groups as Community College Districts, School Facilities Planning Division of the California Department of Education, California Department of Parks and Recreation, Department of Corrections and Rehabilitation, and other state agencies. Summarize task results in a memorandum on task activity and lessons learned.
- Host annual roundtable meetings with state agencies and academic institutions, focusing on presenting the available PIER technology portfolio, sharing, sharing success stories and lessons learned, identifying market trends and needs and establishing future research and demonstration projects and summarize task results in a memorandum on task activity and lessons learned.
- Determine which State agencies require input as to lighting energy efficiency.
- Develop agreements with state agencies and academic institutions to provide technical support on energy-efficient lighting technologies and applications. Technical support will place a strong emphasis on identifying opportunities for PIER-developed technologies and will include the following:
- Site audits and evaluation
- Plan review for new buildings and planned renovations, Interaction with facility managers and end users to understand needs
- Provide technical support during the preparation of lighting-related specifications, codes, and policies
- Provide technical support for lighting procurement, including group procurement initiatives and summarize task results in a memorandum on task activity and lessons learned.
- Develop and maintain contact with the firms and institutions involved in the sustainable buildings effort.
- Inform these firms as to efficient lighting practices especially those highlight PIER technologies.
- Prepare a report describing outreach for technology transfer activities. Submit the draft to the CCM for review and comment, make necessary changes and submit the final report to the CCM. Final task report will serve as a standalone appendix to the Final Report for the overall project.

**Deliverable:**

- 1-2 page memorandum as to relationship development activities.
- 1-2 page memorandum as to Annual Roundtable Meeting Reports
- 1-2 page memorandum on technical support activities.
- 1-2 page memorandum on outreach to the Green Buildings Industry.
- Final Report

# APPENDIX C – UTILITY ROADMAP

## CALIFORNIA UTILITY EMERGING TECHNOLOGY PROGRAM

CLTC will work closely with California IOUs to complete a core set of activities. These activities will directly impact market awareness and acceptance through development of rebate and incentive programs for emerging energy-efficient lighting technologies. CLTC will work with the utilities to identify promising emerging lighting technologies for inclusion in utility lighting portfolios, develop lighting energy/demand savings, and track new lighting technologies entering the market. CLTC activities will be coordinated with individual utilities, and CLTC also expects to coordinate several efforts of interest to all major utility partners.

**Milestones**

- Identify promising emerging lighting technologies for inclusion in utility lighting portfolio.
- Define lighting energy/demand savings needs and opportunities
- Identify lighting technologies to address the needs and opportunities that are available in different stages of development, such as
    - R&D (for future ET portfolio consideration, not in current portfolio
    - Emerging technology (early commercialization)
    - Commercially available but not in widespread use
    - Related efforts (California utility ET, industry organizations, PIER, etc.)
    - Requested support from PG&E Segment Leads and their staff.
- Review inquiries from lighting technology companies promoting new products.
- Prepare Emerging Technologies Opportunity Summary (ETOS) for selected emerging technologies, as requested by the ET Lighting Portfolio Managers.
- Track new lighting developments as directed by the ET Lighting Portfolio Manager, including products in R&D, emerging technologies, and recently commercialized technologies; convey these developments in written and verbal form to ET Lighting Portfolio manager.
- Design and implement assessment projects including the following tasks:
    - Coordinate required access agreements with selected host sites.
    - Develop the testing and monitoring plan for measurement of energy use and photometric impacts of the existing conditions and the technologies.
    - Monitor energy use based on spot power measurements of the existing technology and emerging technologies and short-term monitoring during operating hours.
    - Evaluate photometric impacts
    - Evaluate color quality metrics
    - Schedule and install monitoring equipment as needed for pre-project (existing conditions) and post-project (Emerging Technology) monitoring.
    - Design, distribute and deliver a survey to assess customer satisfaction with the emerging technologies.

**Deliverables**

- 1-2 page memorandum as to emerging lighting technologies appropriate for inclusion in utility ET programs
- 1-2 page memorandum on potential demonstration partners and host sites
- Review and recommendation of manufacturer products, as needed
- ETOS as required
- Pre and post retrofit assessments as required
- Final report of activites

# APPENDIX D - CODES & STANDARDS ROADMAP

## SUPPORT FOR DEVELOPMENT OF CA BUILDING AND APPLIANCE STANDARDS

The purpose of this Task is to inform the building and appliance standards processes of the potential value of energy-efficient lighting products developed during Task 2 and other proven lighting technologies from the PIER program and to foster collaboration between industry and the Commission.

Due to its collaborative, partnership-based operating structure, the CLTC is uniquely positioned as a public entity with a very strong understanding of the needs, desires, and plans of the lighting industry. This market intelligence can be tapped by the Commission to inform the state's building and appliance codes and standards processes of energy savings obtainable from Task 2 and related PIER-funded lighting technologies. By leveraging the knowledge base and industry connections of the CLTC, the Commission could expect their code planning processes to be both more efficacious and more widely supported by the industry.

**Milestones**

- Work with the Commission to provide information about major trends in the lighting industry and their potential effect on shaping CA Title-20 and Title-24 Standards and summarize task results in a memorandum on task activity and lessons learned.
- Work with the Commission and industry to facilitate communication and interaction through roundtable meetings focusing on specific Title-20, Title-24 issues, and legislation related to lighting and daylighting and summarize task results in a memorandum on task activity and lessons learned.
- Provide technical input on lighting and daylighting code and standard development through reviews, comments and suggestions for the 2011 versions of T-20 and T-24 energy standards and summarize task results in a memorandum on task activity and lessons learned.
- Provide technical support and assistance in testing and evaluating technologies to resolve issues and provide information for decision making for specific PIER RD&D lighting technologies and summarize task results in a memorandum on task activity and lessons learned.
- Continue to assist the Energy Commission to resolve critical technical issues as needed and provide technical support to validate the applicability and impact of proposed policies in the lighting area. Summarize task results in a memorandum on task activity and lessons learned.
- Provide 10 hours of expert testimony on behalf of the Energy Commission as may be required in the legislative process.
- Participate in committees and conferences of major lighting, sustainability and energy associations such as those organized by IESNA, NEMA, DOE, USGBC LEED, Energy Star, ASHRAE, etc., provide leadership and technical support for the development of industry standards, such as prescripive and performance metrics, process protocols for measurements, simulations and evaluations and summarize task results in a memorandum on task activity and lessons learned.
- Prepare a report describing all activities and findings, including final specifications of technology and results from laboratory and field testing. Final task report will serve as a standalone appendix to the Final Report for the overall project.

**Deliverables**

- 1-2 page memorandum as to Report on Market Trends
- 1-2 page memorandum as to Hosting of Roundtable with Industry and Commission
- 1-2 page memorandum as to Input on Codes and Standards
- 1-2 page memorandum as to technical support for standards RD&D as needed
- 1-2 page memorandum as to providing technical support for policies as needed
- 1-2 page memorandum on testimony given.
- 1-2 page memorandum as to conferences and associations.
- Final Report

# INFORM LIGHTING STANDARDS & PROCESSES - EVALUATION OF SCOTOPIC LIGHTING EFFECTS

Much has been written about the visual benefits of high color temperature lighting for low-level illumination under dark-adapted eye conditions. Currently, though, there are no established standards for differential illumination levels for high color temperature sources. Many municipalities in the State of California are prepared to institute high color temperature lighting measures without the benefit of established standards.

The Contractor will partner with industry associations, academic institutions, manufacturers and California utilities, such as IESNA, The University of Virginia, manufacturing partners such as Full Spectrum Solutions, Beta Lighting and SCE, to conduct human factors experiments to test the performance of critical visual Tasks under illumination of different color temperatures and intensities. Measurements will include actual Task performance of various populations performing visual Tasks of varying complexity from walking a path to driving a car.

The results of the tests will be used to provide guidance until larger studies can thoroughly establish the differential lighting standards.

**Milestones**

- Collaborate with project partners to identify and select testing sites (Scotopic) in parking lots, recreational sporting venues, ski areas and/or racetracks or other venues as may be available and summarize task results in a memorandum on task activity and lessons learned.
- Work with manufacturing partners such as Full Spectrum Solutions, Metrolight, Luxim and Beta Lighting for design and preparation of light sources with different color temperatures and controls for intensity and summarize task results in a memorandum on task activity and lessons learned.
- Identify selected luminaires for use in subsequent tests.
- Work with industry associations like the Spectral Effects IESNA Committee and academics like Ron Gibbons of Virginia Tech, and the PAC to develop testing protocols for human subjects to use in evaluation of color temperature effects on visibility and summarize task results in a memorandum on task activity and lessons learned.
- Identify a group of test subjects of varying age, gender and racial make-up based on the testing protocol and summarize task results in a memorandum on task activity and lessons learned.
- Work with SCE (or other utility) to install the luminaires in the test sites and prepare the sites for the testing of subjects and summarize task results in a memorandum on task activity and lessons learned
- Implement testing protocols and measure performance of subjects conducting identical visual tasks under different lighting color temperatures and intensities and summarize task results in a memorandum on task activity and lessons learned.
- Evaluate the performance measurement results to determine the relationship between low and high color temperature light levels based on measured performance and summarize task results in a memorandum on task activity and lessons learned.
- Prepare a report describing all activities and findings, including final specifications of technology and results from laboratory and field testing. Final task report will serve as a standalone appendix to the Final Report for the overall project.

**Deliverables**

- 1-2 page memorandum as to identification of scotopic test sites
- 1-2 page memorandum as to development /identification of scotopic fixtures
- 1-2 page memorandum as to creation of scotopic test protocol
- 1-2 page memorandum as to identification of test subjects.
- 1-2 page memorandum as to testing setup
- 1-2 page memorandum as to test protocol implementation
- 1-2 page memorandum as to analysis of subject test results.
- Final Report

# APPENDIX E - TECHNOLOGY TRANSFER ROADMAP

## PROGRAM-WIDE MARKET CONNECTIONS STRATEGY

CLTC will define program-wide market connections strategy that unifies market connectivity for the energy-efficient lighting products developed during the next three years. The Program-wide Market Connections Strategy is intended to guide the entire set of energy-efficient lighting solutions developed in Task 2 to achieve a level of market acceptance consistent with reaching energy savings goals, to inform energy codes and other processes, and to identify future market-driven public interest lighting research opportunities. This strategy will also ensure projects progress according to schedule, partners maintain clear communication and information is disseminated in an appropriate fashion.

**Milestones**

- Develop the concepts into a detailed plan for program-wide market connections.
- Present the market connections strategy to the PAC, making revisions to the plan as needed.
- Obtain CCM approval of the Program-wide Market Connections Plan for implementation.
- Prepare a report describing Program Market Connections activity conducted throughout the agreement

**Deliverables**

- Report on Program Market Connections

## PARTNERSHIP DEVELOPMENT/TECHNOLOGY TRANSFER TO LIGHTING INDUSTRY

While there are many major lighting manufacturers that supply California, the majority of their divisions as well as the typical manufacturer in California are still a hand-assembly operation. These firms are perceiving the state's policy shifts towards energy efficiency lighting, as exemplified by AB1109 of 2007 (Huffman), but they generally lack expertise in the areas of advanced electronics, optics, thermals and controls to be able to build next generation lighting fixtures. As such, they have not typically taken advantage of the public specifications made available by PIER, with the result that the California marketplace does not have a rich/diverse set of energy-efficient lighting products. CLTC will form and work with a stakeholder task force aligned with industry associations like ALA and various LED, driver, optic and controls makers to provide training that will allow manufacturers to produce energy-efficient lighting products.

**Milestones**

- Form a Stakeholder task force including the manufacturing partners such as ALA, Lumileds, Osram Opto, Samsung, Advance Transformer, Exclara to identify the necessary components of a training curriculum for fixture manufacturers and summarize task results in a memorandum on task activity and lessons learned.
- Assemble/prepare the training curriculum, determine the deployment steps, and summarize task results in a memorandum on task activity and lessons learned.
- Upon CCM approval, conduct beta class trainings in several locations to test the curriculum package. Based on feedback from the beta classes, revise the curriculum and, obtain approval from the CCM,
- Distribute curriculum to stakeholder groups for use in conducting training sessions throughout the State and summarize task results in a memorandum on task activity and lessons learned.
- Prepare a report describing all activities and findings, including final specifications of technology and results from laboratory and field testing. Final task report will serve as a standalone appendix to the Final Report for the overall project.

**Deliverables**

- 1-2 page memorandum as to Stakeholder Task force creation
- 1-2 page memorandum as to initial curriculum
- 1-2 page memorandum as to beta class training, curriculum revision and distribution
- Final Report Appendix

## PIER TECHNOLOGY SUPPORT

The purpose of this task is to accelerate lab to the marketplace connections of PIER research through a number of technology transfer activities with industry and research communities. These activities include organizing and hosting roundtable meetings and conferences/forums as well as producing and managing outreach materials such as www.thelightingportal.com and guidelines for energy efficient lighting practice.

**Milestones**

- Host three annual roundtable meetings with academic institutions to exchange ideas on how to improve their adoption of PIER technologies in the energy efficiency arena. Areas of focus for the roundtable meetings will include the current PIER portfolio and methods to educate and train professionals on their installation and operation and summarize task results in a memorandum on task activity and lessons learned.
- Host three annual Industry-Utility forums as a State-wide event. Areas of focus of the forum will vary from year to year to address emerging needs and opportunities. The focus of the planned forums will be determined in collaboration with industry and utilities and summarize task results in a memorandum on task activity and lessons learned.
- Prepare a Residential Lighting Guide that updates the version issued for the 2005 Title 24 requirements, reflecting the changes mandated by the 2008 Title 24 standards and including new technology solutions such as solid state lighting
- Prepare an Office lighting design guide
- Prepare a hospitality facility (Hotel/motel) lighting guide
- Prepare a Daylight harvesting controls guide for both skylit and sidelit spaces
- Extend the existing daylighting sections and organize them together with additional sections into a new Advanced Lighting Guideline (ALG) Daylighting Chapter.
- Extending the light sources and controls sections to include information about LED and induction light sources, luminaires and controls.
- Expand The Lighting Portal web site with by the addition of self-sustaining functionality, such as a secure Group Purchasing Program that will allow DGS, UC, CSU and CCC units to consolidate their purchases of PIER technologies to steeply reduce the costs. The content-enhancement work will focus on streamlining the web site to best serve the communication needs of key participant groups. Add video clips and other content-enhancements demonstrating PIER technologies and summarize task results in a memorandum on task activity and lessons learned.
- Work in collaboration with utilities and industry to develop training programs that will produce trained professionals for the installation, commissioning, operation and maintenance of new and emerging energy efficient lighting technologies.
- Assist the curriculum collaborators by developing training programs and contributing to education and training efforts through curriculum development, lectures and seminars and summarize task results in a memorandum on task activity and lessons learned.
- Prepare a report describing outreach for PIER technology support activities. Final task report will serve as a standalone appendix to the Final Report for the overall project.

**Deliverables**

- 1-2 page memorandum on status of Annual Academic Roundtables
- 1-2 page memorandum as to Annual Utility-Industry Forums
- 1-2 page memorandum as to design guides development
- 1-2 page memorandum as to enhancements to Advanced Lighting Guidelines 2009
- 1-2 page memorandum as to sustainability and content-enhancement of The Lighting Portal.

- 1-2 page memorandum as to professional development training.
- Final Report

## DEVELOP UNIVERSITY-LEVEL TRAINING PROGRAM FOR DESIGN PROFESSIONALS

The objective of this task is to provide design professionals with knowledge about energy efficient lighting strategies and technologies (Lighting Lectureship Program). There are currently no University level courses to teach this material. This has been requested by the design community, utilities and the University. Such a program should provide the design professional community with an understanding of new technologies (particularly PIER technologies) and their proper application for compliance with new Title 20 code, Title 24 code and UL/IESNA standards.

**Roadmap**

- Meet with stakeholders such as AIA, IALD, and higher education institutions to determine optimal content requirement and other factors for successful coursework and summarize task results in a memorandum on task activity and lessons learned.
- Offer the initial course and seek University of adoption of it in future curricula and summarize task results in a memorandum on task activity and lessons learned.
- Prepare a report describing recommendations to develop/maintain the lectureship program under this task. Final task report will serve as a standalone appendix to the Final Report for the overall project.

**Deliverables**

- 1-2 page memorandum as to development of Lighting Lectureship Program
- 1-2 page memorandum as to adoption of Lighting Lectureship Program
- Final Report

## PROGRAM-LEVEL PRODUCTION READINESS PLANS AND POST CONTRACT SUPPORT STRATEGIES

The objective of this task is to bring the Production Readiness Plans and Post Contract Support Strategies together where the results of all tasks can easily be accessed.

**Milestones**

- Combine all of the individual project-levels production readiness programs into a single comprehensive document and summarize task results in a memorandum on task activity and lessons learned.
- Combine all of the post contract support strategies into single comprehensive document and summarize task results in a memorandum on task activity and lessons learned.
- Prepare a report describing Post Production Readiness Program support Strategies. Final task report will serve as a standalone appendix to the final report for the overall project.

**Deliverables**

- 1-2 page memorandum as to project-level production readiness programs
- Final Report

**Exhibit B, Attachment B-2**
**PIER Budget**

| Budget for PIER Reimbursement to Prime Contractor | | Personal Services | | Project Operating Expenses | | | | | | Fees | | | PIER Reimburs-ableTask Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| California Lighting Technology Center | | Direct Labor | Fringe Benefits | Materials | Equipment | Travel | Misc. | Minor Subcon-tractors | Major Subcon-tractors [1] | Indirect Overhead | G&A | Profit [2] | |
| **1.0** | **Project Administration Activities** | | | | | | | | | | | | |
| **1.1** | Attend Kick-off Meeting | 4,246 | 1,404 | | | | | | 0 | 1,413 | 1,770 | | 8,833 |
| **1.2** | CPR Meetings | 2,123 | 702 | | | | | | 0 | 706 | 885 | | 4,416 |
| **1.3** | Final Meeting | 4,246 | 1,404 | | | | | | 0 | 1,413 | 1,770 | | 8,833 |
| **1.4** | Monthly Progress Reports | 9,166 | 2,800 | | | | | | 0 | 2,992 | 3,749 | | 18,707 |
| **1.5** | Test Plans, Technical Reports and Interim Deliverables | | | | | | | | | | | | |
| **1.6** | **Final Report** | **12,738** | **4,212** | **0** | **0** | **0** | **0** | **0** | **0** | **4,238** | **5,311** | **0** | **26,499** |
| **1.6.1** | Final Report Outline | 8,492 | 2,808 | | | | | | 0 | 2,825 | 3,541 | | 17,666 |
| **1.6.2** | Final Report | 4,246 | 1,404 | | | | | | 0 | 1,413 | 1,770 | | 8,833 |
| **1.7** | Identify and Obtain Matching Funds | | | | | | | | | | | | |
| **1.8** | Identify and Obtain Required Permits | | | | | | | | | | | | |
| **1.9** | Electronic File Format | | | | | | | | | | | | |
| **1.10** | Establish the aPAC | 1,528 | 467 | | | | | | 0 | 499 | 625 | | 3,119 |
| **1.11** | Conduct aPAC Meetings | 9,166 | 933 | | | | | | 0 | 2,525 | 3,164 | | 15,788 |
| | **Administration Activities Subtotals** | 43,213 | 11,922 | 0 | 0 | 0 | 0 | 0 | 0 | 13,786 | 17,274 | 0 | 86,195 |
| | **Project Technical Activities** (Delete rows as necessary) | | | | | | | | | | | | |
| **2.0** | **Daylighting/Electric Lighting Integration** | | | | | | | | | | | | 0 |
| **2.1** | **Commercialize Dual Loop Skylight Controls** | 38,800 | 15,696 | 5,500 | | 4,080 | 15,000 | 15,000 | | 19,769 | 17,076 | | 130,921 |
| **2.2** | **Smart Windows & Skylights** | 90,948 | 26,210 | 14,500 | | 3,600 | | 10,000 | | 36,315 | 42,817 | | 224,390 |
| **2.3** | **Dual Loop Controls for Side-Daylighting** | 19,512 | 8,954 | 5,000 | | 1,000 | | 4,000 | | 9,616 | 74,306 | | 122,388 |
| **2.4** | **Daylight Optimization for Skylights** | 72,266 | 20,904 | 14,000 | | 3,700 | | 7,500 | | 29,593 | 32,461 | | 180,424 |
| **2.5** | **Solar Canopy for Core Daylighting** | 68,588 | 19,954 | 5,000 | | 3,600 | | 10,000 | | 26,786 | 29,897 | | 163,825 |
| **2.6** | **Develop Exterior Lighting Technologies / High-Efficiency Bi-level Smart Wall-** | 44,743 | 13,815 | 16,998 | | 3,100 | | | | 19,664 | 18,353 | | 116,673 |
| **2.7** | **LED/Induction Longevity in Ext. Applications** | 48,227 | 12,025 | 13,500 | | 1,000 | | 18,000 | | 23,188 | 20,144 | | 136,083 |
| **2.8** | **Smart Dark-Sky Historical Lighting** | 44,863 | 13,817 | 6,499 | | 3,100 | | | | 17,070 | 18,353 | | 103,701 |
| **2.9** | **Side Projecting LEDs w/ PV Power and Controls** | 59,599 | 20,730 | 18,000 | 25,000 | 3,100 | | | | 25,358 | 29,735 | | 181,523 |
| **2.10** | **Develop Interior Lighting Technologies/Retrofit LED Downlights /** | 37,855 | 11,563 | 6,499 | 25,000 | 6,200 | | | | 15,529 | 15,498 | | 118,144 |

**Exhibit B, Attachment B-2**
**PIER Budget**

| Budget for PIER Reimbursement to Prime Contractor | | Personal Services | | Project Operating Expenses | | | | | | Fees | | | PIER Reimburs-ableTask Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| California Lighting Technology Center | | Direct Labor | Fringe Benefits | Materials | Equipment | Travel | Misc. | Minor Subcon-tractors | Major Subcon-tractors [1] | Indirect Overhead | G&A | Profit [2] | |
| **2.11** | **NEMA Digital Controls Commisioning Tool** | 32,371 | 8,910 | 1,100 | | | | 60,000 | | 25,595 | 12,935 | | 140,911 |
| **2.12** | **Wallwash for Task-Ambient Strategies Demand Response Office Lighting** | 51,122 | 19,074 | 18,000 | 8,000 | 2,520 | | | | 22,679 | 26,427 | | 147,822 |
| **2.13** | **Plasma Luminaires for High Bay, Pole Lights, and Office Applications** | 37,544 | 11,460 | 23,996 | 40,000 | 3,360 | | | | 19,090 | 15,356 | | 150,806 |
| **2.14** | **OLEDs for Office Ambient Lighting** | 31,614 | 11,930 | 8,499 | | 1,400 | | | | 13,361 | 15,513 | | 82,317 |
| **2.15** | **Next Gen. LED Residential Lighting & Manuf. Training** | 47,549 | 17,630 | 52,100 | | 6,200 | | | | 30,870 | 25,518 | | 179,866 |
| **2.16** | **CPR for R&D Activities** | 2,148 | 791 | | | 150 | | | | 772 | | | 3,861 |
| **3.0** | **Program-wide Market Connections Element** | | | | | | | | | | | | |
| **3.1** | **Program-wide Market Connections Strategy** | 3,128 | 709 | 1,000 | | 111,350 | 109,300 | | | 56,372 | 1,202 | | 283,060 |
| **3.2** | **Technology Transfer Plan** | 2,905 | 663 | | | | | | | 892 | 1,118 | | 5,578 |
| **3.3** | **Partnership Development/Technology Transfer to Lighting Industry** | 11,619 | 3,292 | | | | | | | 3,728 | 4,672 | | 23,311 |
| **3.4** | **Develop university-level training program for design professionals** | 14,524 | 3,666 | | | | | | | 4,548 | 5,700 | | 28,438 |
| **3.5** | **DGS Program** | 57,565 | 14,088 | 1,716 | | 4,010 | | 10,000 | | 22,513 | 19,612 | | 129,504 |
| **3.6** | **Inform Codes and Standards Processes/Eval. Of Scotopic Light.** | 32,280 | 9,151 | 4,500 | | 2,800 | | 1,000 | | 13,315 | 14,088 | | 77,134 |
| **3.7** | **Support for Development of Calif. Build & Appliance Codes & Standards** | 19,446 | 4,418 | 3,000 | | | | | | 4,644 | 7,477 | | 38,985 |
| **3.8** | **Market Adoption/Outreach for Tech. Transfer** | 38,563 | 8,681 | 3,000 | | | | 40,000 | | 22,561 | 14,803 | | 127,608 |
| **3.9** | **PIER Technology Support** | 58,939 | 13,478 | 36,000 | | 6,480 | | 15,000 | | 28,775 | 22,691 | | 181,363 |
| **3.10** | **Program-level Production Readiness Plans and Post Contract Support** | 14,524 | 3,315 | 2,000 | | | | | | 4,960 | 6,510 | | 31,309 |
| **3.11** | **CPR for Program-wide Market connections** | 2,148 | 791 | | | 150 | | | | 772 | | | 3,861 |
| | **Technical Activities Subtotals** | 983,390 | 295,713 | 260,407 | 98,000 | 170,900 | 124,300 | 190,500 | 0 | 498,333 | 492,262 | 0 | 3,113,805 |

| **Prime Contractor** | Direct Labor | Fringe Benefits | Materials | Equipment | Travel | Misc. | Minor Subcon-tractors | Major Subcon-tractors | Indirect Overhead | G&A | Profit | Total PIER Reimburs- able Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **PIER Reimbursable Totals** | **1,026,603** | **307,635** | **260,407** | **98,000** | **170,900** | **124,300** | **190,500** | **0** | **512,119** | **509,536** | **0** | **3,200,000** |
| **Percent of the Total** | 32% | 10% | 8% | 3% | 5% | 4% | 6% | 0% | 16% | 16% | 0% | 100% |
| | | | | | | Total project expenses = | | 844,107 | Total overhead & profit = | | 1,021,655 | |