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Print

2013 TITLE 24, PART 6

RETAIL LIGHTING

A guide to meeting, or exceeding,
California's 2013 Building Energy Efficiency Standards

DEVELOPED BY THE CALIFORNIA LIGHTING TECHNOLOGY CENTER, UC DAVIS

NAVIGATING TITLE 24, PART 6

	MANDATORY	PREScriptive	PERFORMANCE
ADDITIONS, ALTERATIONS AND REPAIRS	\$141.080f \$141.080K	\$141.080f \$141.080K	—
Additions	—	\$141.08a1	\$141.08a2
Alterations	\$141.08b2a/ \$141.08b2b Table 141.D-E	\$141.08b2a/ \$141.08b2b Table 141.D-F	\$141.08b2a/ \$141.08b2b Table 141.D-G
Luminous Modifications-in-Place	\$141.08c2 Table 141.D-F	\$140.8 \$141.08c2a/ \$141.08c2b Table 141.D-F	—
Light Wiring Alterations	\$130.1 \$130.4 \$130.502a	—	—
Repairs	\$110.36d	—	—
GENERAL LIGHTING CONTROLS AND EQUIPMENT	\$130.0	—	—
Manual Area Controls	\$130.1af	—	—
Multi-level Controls	\$130.1bf	—	—
Automatic Shut-Off (Occupant Sensing Controls)	\$130.1cf	—	—
CONTROL DEVICES AND SYSTEMS, BALLASTS, AND LUMINAIRES	\$110.9	—	—
Time-Switch Lighting Controls	\$110.9bf1	—	—
Daylight Controls	\$110.9bf2	—	—
Dimmer	\$110.9bf3	—	—
Occupant-Sensing Controls	\$110.9bf4	—	—
Track Lighting Integral Current Limiter	\$110.9ig	—	—
Track Lighting Supplementary Occupant Protection Panel	\$110.9ig	—	—

RETAIL LIGHTING GUIDE | 20

CHAPTER 1 CONCEPTS & PRINCIPLES

INTRODUCTION

THE BENEFITS OF EFFICIENCY

Bigger Energy Savings
Lighting is one of the largest electricity loads in commercial buildings, representing approximately 20% of total energy use. Title 24's energy efficiency requirements of California's Title 24, Part 6 Building Energy Efficiency Standards (BES) aim at reducing electricity use while maintaining high-quality lighting.

Smarter Lighting
Dimmable light sources paired with advanced lighting controls save energy while adding functionality to lighting designs. Today's retail spaces often serve multiple functions. Merchandise displays may be constantly changing, and the lighting system must accommodate lighting easily and easily, maximizing the impact of new displays while saving energy time.

Better Branding
Consumers have become increasingly concerned about their impact on the environment. Sustainable products and practices are key to building brand loyalty. Retailers have responded by increasing the sustainability of their products and packaging. Sustainable lighting systems not only reduce energy use and lowers overhead costs for retailers, but also provides an opportunity for business growth.

Market research now indicates that companies with sustainability initiatives tend to profit more and perform better than competitors without these programs. Sustainable lighting is also being recognized as a source of innovation and a way to improve the appeal of retail brands.¹

1. National Commercial End-User Survey (NCES), March 2006, California Energy Commission
2. ** 2012 Retail Sustainability Report: Fueling Continuous Development, 2013, Retail Industry Leaders Association
3. The Innovative Bright Line: Findings from the 2012 Sustainability and Innovation Global Executive Study and Research Report, February 2013, GFI Sustainable Management Institute

CONCEPTS & PRINCIPLES

COLOR CHARACTERISTICS

Color Temperature (CCT)
Correlated color temperature (CCT) indicates the warmth or coolness of the light emitted by a light source. Light with a higher CCT value is perceived as cooler, while light with a lower CCT value is perceived as warmer. Cool light (2,700–3,000K) give off light that is warm in appearance. Sources with higher CCT values (4,000–6,500K) provide light with a cooler color appearance.

Specifying Color
Specifying color is important for maintaining some consistency in the appearance of various light sources. Check the Lighting Facts label for information on CCT (or "light color"), lumen output, power consumption (watts), and efficacy.

Color Rendering (CRI)
The Color Rendering Index (CRI) is the current industry standard for measuring how accurately a light source renders the colors of the objects it illuminates. The maximum CRI value is 100. In CRI testing, indoor commercial applications should have a minimum CRI of 80. Light sources with a CRI of 80 or higher are considered acceptable for most indoor applications. Light for use in retail applications, lighting for use in retail areas with color-critical products should be specified with a high CRI value.

Specifying Lamps and Luminaires with Similar Color Rendering Properties
Specifying lamps and luminaires with similar color rendering properties help ensure wall color, carpeting and other materials have a consistent appearance, especially in adjoining spaces. The LED lighting industry has adopted a color rendering index (CRI) of 80 as the standard. But the black-and-white Federal Trade Commission label does not. Most manufacturers can supply information on CRI if it is on product packaging or literature.

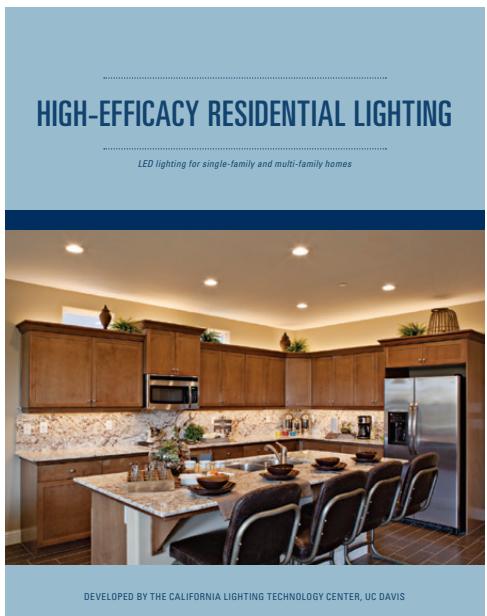
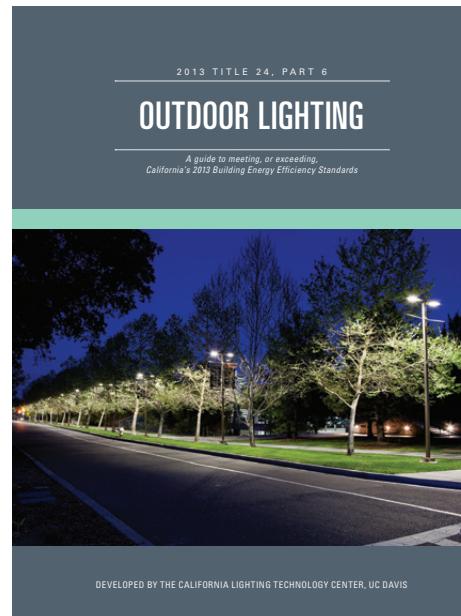
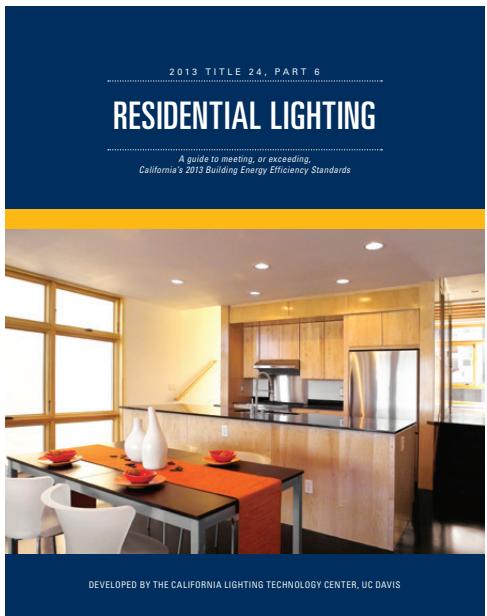
Converting Color Quality
The LED-MR16 series used for the对照灯 (left) and对照灯 (right) were produced under different conditions. The difference is that the left lamp was measured against a reference color (white) and the right lamp was measured against a reference color (red). The color rendering index (CRI) for the left lamp is 89, while the CRI for the right lamp is 95. Both lamps have a CRI of 80.

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2013 Title 24, Part 6 Lighting Code Guides & Training Materials

2012–2015

Project Partner: Pacific Gas and Electric, California Energy Commission



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Title 24 Building Energy Efficiency Standards

2013 TITLE 24, PART 6 BUILDING ENERGY EFFICIENCY STANDARDS

FOCUS AREAS

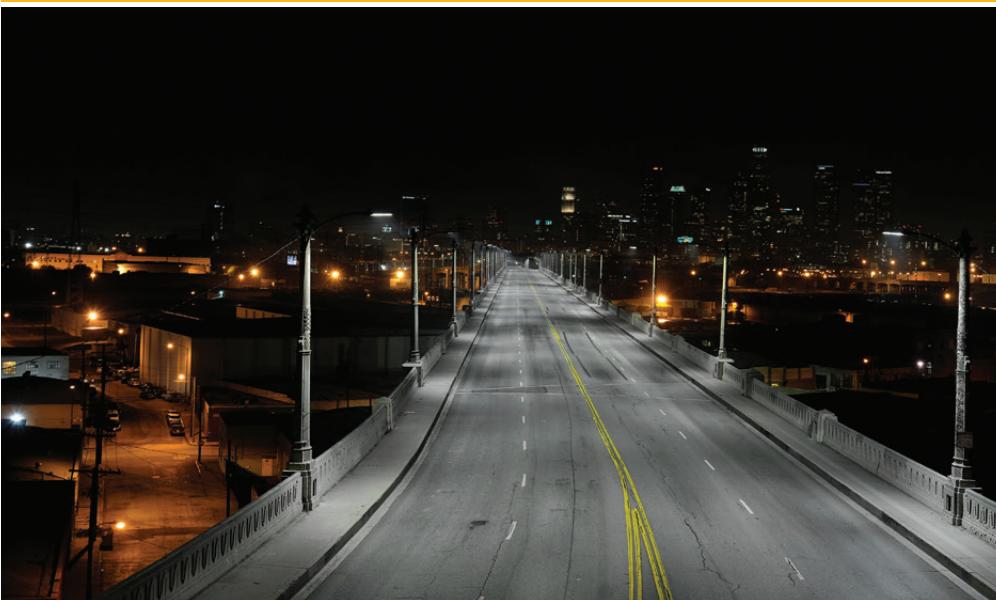
- Residential Lighting
- Retail Lighting
- Office Lighting

The lighting portion of the 2013 Title 24 code incorporates technologies developed through CLTC's work with the Public Interest Energy Research (PIER) program and demonstrated through the State Partnership for Energy Efficient Demonstrations (SPEED). SPEED program demonstrations provided evidence of the effectiveness, feasibility and affordability of adaptive lighting technologies added to the new state codes and standards. CLTC is also involved in outreach and education efforts aimed at helping professionals meet—or exceed—Title 24 standards.

These resources are not intended to replace the Energy Commission's comprehensive Title 24 Building Energy Efficiency Standards or its compliance manuals. They are simply intended to help designers and building professionals become familiar with advanced lighting technologies and the latest code improvements.

THE STATE OF STREET LIGHTING IN CALIFORNIA, 2012

A STUDY OF PUBLIC INFRASTRUCTURE & ENERGY USE IN CALIFORNIA



CALIFORNIA LIGHTING TECHNOLOGY CENTER | UNIVERSITY OF CALIFORNIA, DAVIS

The State of Street Lighting in California, 2012

2012–2015

Project Partner: Chevron

THE SURVEY

Determining the state of street lighting in California



As part of a comprehensive study of our statewide infrastructure, the California Lighting Technology Center (CLTC) at the University of California, Davis asked municipal staff across the state to help map out the current distribution of street light ownership and street light technologies in California. CLTC's research staff achieved an unusually high response rate (43 percent) for surveys of this type. Representatives from 212 California cities shared data on approximately 1.1 million municipal street lights.

The survey posed nine questions regarding cities' goals for energy efficiency, as well as the number and type of street lights within each city. Seventy-four percent of respondents rated energy efficiency as a "high" or "very high" priority, with 29 percent reporting that their city has passed a climate action plan or similar sustainability initiative. The data collected through the survey indicate that cities with climate action plans or sustainability initiatives in place are significantly more likely to have invested in street lighting retrofits aimed at increasing energy efficiency. But the data also indicate that a large portion of California's street lights have not yet been upgraded to utilize more energy-efficient street light technologies.



2 THE STATE OF STREET LIGHTING IN CALIFORNIA, 2012

HOW CURRENT ARE CALIFORNIA'S STREET LIGHTS?

The survey revealed that 76 percent (852,000) of the cities' street lights use high-pressure sodium (HPS) lamps. Until recently, HPS was the most cost-effective technology available, but now they are far from the best choice on the market. HPS lights consume about twice the energy as more advanced lighting technologies, such as LED and induction lamps. They also have a significantly shorter life span and measure poorly on the color rendering index (CRI), casting everything they illuminate in yellow light. Though more efficient alternatives exist, survey data indicate that just 2 percent of the street lights reported use LEDs and only 3 percent have induction light sources.

WHO OWNS CALIFORNIA'S STREET LIGHTS?

Close to 54 percent of street lights in the survey (about 605,000 of the 1.1 million street lights reported) are city-owned and city-maintained. Results also indicate that cities with a higher proportion of city-owned, city-maintained street lights are significantly more likely to have adopted more advanced street light technology (namely, LED or induction lamps).

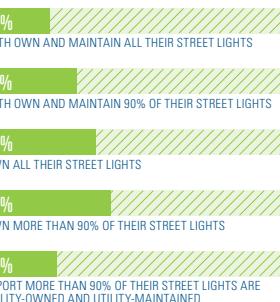
Roughly one-third (over 353,000 street lights) are reportedly utility-owned and utility-maintained. Approximately 5 percent (58,861) were described as city-owned and third-party maintained, and close to 5 percent (48,663) are reportedly city-owned and maintained by a utility. (Street light ownership and maintenance were not reported for roughly 5 percent (50,788) of the total street lights described by survey respondents.)

TOTAL NUMBER OF STREET LIGHTS REPORTED:
1.1 MILLION

76% HPS

A total of 852,000 of the street lights surveyed still use high-pressure sodium lamps.

Most cities report owning some, but not all, of the street lights within their city limits. Of the 212 California cities surveyed:



THE STATE OF STREET LIGHTING IN CALIFORNIA, 2012 3

SPEED State Partnership for Energy Efficient Demonstrations

SPEED TECHNOLOGIES

Part of California's commitment to a clean energy future

The State Partnership for Energy Efficient Demonstrations (SPEED) program drives the market adoption of energy efficient technologies. Managed through the California Institute for Energy and Environment (CIEE), SPEED has conducted more than 100 demonstrations and other technology-transfer projects across the state, showcasing the benefits of best practices and state-of-the-art solutions.

The innovations developed through the SPEED program are commercially available through a number of manufacturers. Many of these strategies will be required under California's 2013 Title 24 Energy Efficiency Standards. Details, including case studies and product information, are available at the SPEED website.

For more information, visit partnershipdemonstrations.org

CUMULATIVE ANNUAL TARGETS IN CALIFORNIA

- 100 million** kWh of electricity
- \$20 million** cost savings
- 7 million** tmb of natural gas
- 100,000 tons** CO₂ reduction

ADAPTIVE CORRIDOR CONTROL SCENARIOS

The following four scenarios are specific examples of the three types of control strategies just described. These technology combinations are not the only ways to achieve deep energy savings, but they have been vetted through real-world SPEED demonstrations. All support compliance with 2013 Title 24 (Section 130.1), which requires occupant-sensing lighting controls in corridors. Other manufacturers offer similar solutions. Energy and cost savings for this business case are calculated per fixture, based on improvements to incumbent lighting. The SPEED team selected the common 2-lamp 2x4 T8 recessed fluorescent fixture to serve as the incumbent example.¹

SCENARIO 1 – ZONAL
70% ENERGY SAVINGS

The Lutron Energi TriPak control system utilizes Lutron DALI ballasts, wired to the central PowPak relay module. The PowPak communicates with wireless, battery powered sensors to control the lights based on occupancy.

SCENARIO 2 – FIXTURE-INTEGRATED
72% ENERGY SAVINGS

This scenario uses PIR fixture-integrated occupancy sensors from WattStopper in tandem with 0–10V dimming ballasts. This strategy saves somewhat more energy than Scenario 1, but it does not offer features and benefits like Auto DR, maintenance event e-mails, or remote, dynamic monitoring and control.

SCENARIO 3 – NETWORKED
76% ENERGY SAVINGS

The Enlighted network control system provides occupancy sensors for every fixture, much like Scenario 2. Unlike Scenario 2, these sensors also communicate wirelessly with a gateway, which is the central node for the system. In any given installation, a number of gateways will be deployed. These gateways then communicate with an Energy Manager, which connects to the Internet. This allows a facility staff member to monitor, program and control light fixtures remotely, from any Internet connection. This system also yields deeper energy savings, thanks to options and features such as high and low-level trim, DR responsiveness, and easy connection with existing building energy management systems.

SCENARIO 4 – NETWORKED + LED
86% ENERGY SAVINGS

For maximum lighting efficiency, facilities can install LED fixtures with dimmable drivers along with the network control components described in Scenario 3. For this specific analysis, the FineLite HPR 2x4 troffer was utilized. Networked LED lighting (Scenario 4) involves higher up-front costs, but it is actually a very attractive choice for campuses planning new construction or major renovation projects. The economic reasons behind this are explored on the pages that follow.

¹ Nationwide, linear fluorescent lamps constitute 80% of light sources in commercial buildings, according to the DOE's 2010 U.S. Lighting Market Characterization, published January 2012.

ADAPTIVE CORRIDOR LIGHTING | 3

SPEED State Partnership for Energy Efficient Demonstrations

EXTERIOR LIGHTING CASE STUDY

ADAPTIVE LED WALL PACKS
University of California, Davis

In 2012, UC Davis upgraded its exterior lighting as part of the university's Smart Lighting Initiative. Wall packs on campus were replaced with adaptive LED wall packs with dimmable LED sources, motion sensors, and wireless controls. This allowed the units to be incorporated into an adaptive lighting system. The new system offers an intelligent, networked approach to lighting and energy management, with improved lighting quality and optimal energy efficiency.

ENERGY & CO₂ SAVINGS
89%

OCUPANCY RATE
20%

LIFETIME MAINTENANCE SAVINGS
\$233 per fixture

LIFETIME ENERGY COST SAVINGS
\$753 per fixture based on UC Davis rate of \$0.075/kWh

For more information, visit PARTNERSHIPDEMONSTRATIONS.ORG

NETWORKED ADAPTIVE EXTERIOR LED LIGHTING
University of California, Davis

In order to reduce energy consumption and the state's carbon footprint, the California Public Utilities Commission (CPUC) has called for a 60–80% reduction in lighting energy consumption by 2020. Answering this call, UC Davis set out to reduce campus-wide lighting electricity consumption at least 60% below 2007 levels. The first phase of this program involved the replacement of all legacy streetlights with networked LED streetlights, area lights, post-top fixtures and wall packs. The "ultra-sensor" lighting installation is saving energy and costs.

ENERGY & CO₂ SAVINGS
73–87%

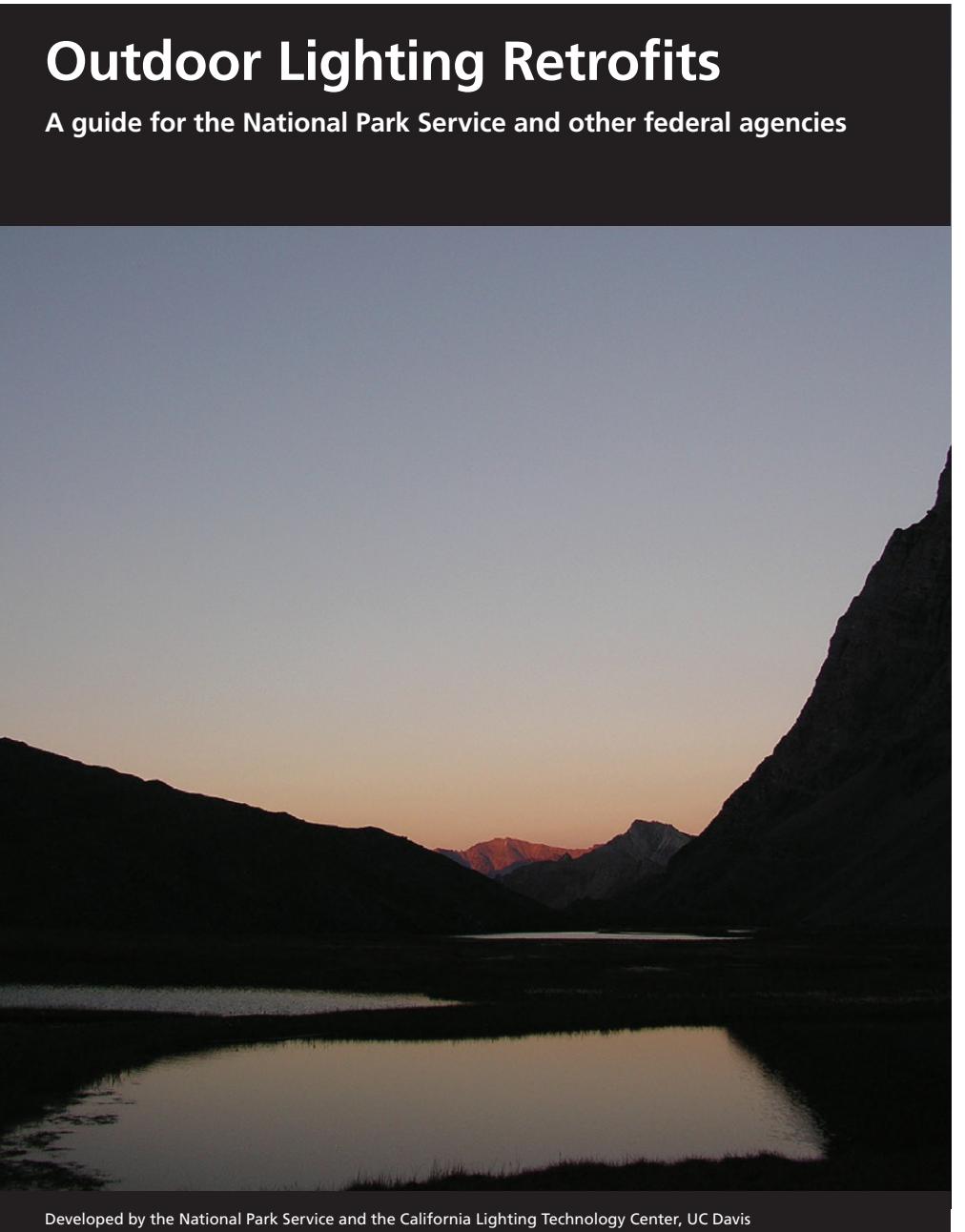
OCUPANCY RATE
20–59%

LIFETIME MAINTENANCE SAVINGS
\$X per fixture

LIFETIME ENERGY COST SAVINGS
\$X per fixture based on UC Davis rate of \$0.075/kWh

"We're exceeding what we anticipated in terms of kilowatt-hour savings," says Scott Amman, Senior Project Manager with UC Davis Design and Construction Management. "It's a win-win. We would save a lot of energy and money with a system like the one at UC Davis." The project also put UC Davis's exterior lighting in compliance with California's lighting energy efficiency standards (Title 24 Part 6). Under the code, all luminaires that consume 75 watts or more and are mounted at 24' or below must be controlled with motion sensors in addition to photocensors and automatic scheduling controls.

ADAPTIVE LED LIGHTING: UNIVERSITY OF CALIFORNIA, DAVIS | 1



Outdoor Lighting Retrofits

2014

Project Partner: National Park Service

Reduced Maintenance Costs

A lighting retrofit can often deliver reduced maintenance costs over the life of the new lighting system as compared to the existing system. For example, improvements in lighting technologies have led to increased lamp life, which reduces the time between scheduled maintenance tasks such as lamp replacement, which reduces labor costs and other expenses. In addition, improved reliability reduces maintenance and further reduces operational costs associated with maintenance.

Maintenance savings may also help offset some of the initial cost of a lighting retrofit project. For example, LED sources continue to decrease, as their efficacy continues to increase, resulting in greater energy savings and a better return on investment.

Improved Visual Environments

Lighting retrofits can help address general lighting quality problems. For example, sodium vapor lamps are often used with better color rendering characteristics and reduced flicker and added noise. When discussing outdoor lighting characteristics, it is important to understand correlated color temperature (CCT) and color rendering index (CRI). In addition, surrounding visual conditions influence the way we perceive light in the outdoor environment.

Correlated Color Temperature (CCT)

Correlated color temperature (CCT) indicates the color appearance of a light source and is measured in Kelvin (K), which is a measure of the color of light emitted by a source that correlates the color to that of an ideal blackbody radiator. The color of light emitted by a blackbody radiator depends exclusively on its temperature. As a blackbody radiator heats up or cools down, the color appearance of the light it emits varies. The higher the temperature, the "bluer" the color appearance of the light it emits (see figure 2). Conversely, most general illumination LED sources have high CCT (~5000K) and deliver orange-yellow light. In contrast, most general illumination LED sources have high CCT (~2000K) and deliver white light that is relatively cooler in appearance.

Figure 2. A more in-depth perspective on color specification uses the International Commission on Illumination (CIE) 1976 x,y chromaticity diagram. Here, specific color matching can be achieved by plotting the chromaticity coordinates of light samples against the chromaticity coordinates of the reference light source (represented by the black line cutting through the middle of figure 3).

Color Rendering Index (CRI)

Color rendering index (CRI) is a measure that describes how accurately a light source renders color. CRI uses eight standard color samples to compare the color rendering ability of a light source with that of a reference light source, usually a sodium vapor light source. The color of each sample is measured under the test light source and compared to the color of the same sample under the reference light source. The degree of color shift between the two sets of measurements is calculated and grouped as an average. This average is called the color rendering index (CRI). CRI ranges from 0 to 100, where 100 means the best color rendering. A more light source appears to emit a single color, but in reality, a light source emits many different colors simultaneously. This spectrum deconstructed into its individual colors is called spectral power distribution, or SPD. SPD is usually plotted as a graph showing the relative power of each wavelength. The visible spectrum of light wavelengths ranges from approximately 380–700 nm. CCT and CRI are two ways of describing a light source's SPD into a single number.

8
9

Part 2 Best Practice Strategies

A successful lighting installation delivers the right light, in the right place, only where and when it is needed.

Basic Steps for a Lighting System Retrofit or New Lighting Installation

- Perform a lighting system audit.** Before beginning a lighting system retrofit, a lighting audit of the existing system should be performed to determine the system's performance, how it meets the area's lighting needs, opportunities for improvement, and the physical characteristics of the system. These include the physical dimensions of the space, as well as the mounting heights and locations of existing luminaires and lighting controls. A section on lighting audits is provided later in this guide.
- Establish goals for the retrofit or new lighting system design.** The results of the lighting audit will help identify which aspects of the existing system need improvement. These needs, in turn, will clarify the goals of the retrofit, e.g., to improve energy efficiency, reduce maintenance costs, or extend the life of the system.
- Identify appropriate light sources and lighting controls.** The needs of the outdoor space and the retrofit goals will determine which lamps, luminaires or lighting controls are best suited to the project. A section on light sources, light fixtures and lighting controls is also provided.
- Obtain a code-compliant lighting design.** Lighting plans must meet, or exceed, the federally mandated standards set forth by ASHRAE 90.1-2010. Before beginning a lighting system retrofit, it is recommended to review the applicable codes and standards. A professional computer-aided design package (e.g., AGI 32, Radiance, or Visual Pro) or IES Recommended Practice appendices can be used to perform a lighting design.
- Verify application-specific light levels and distribution patterns meet best-practice guidelines.** The results of the lighting audit will help identify the needs of different systems under consideration. Remember to factor in projected increases in energy costs, potential energy savings from lighting controls, replacement and disposal costs, and environmental impact.
- Perform a lifecycle cost-benefit analysis.** This section provides a brief overview of the costs of different systems under consideration. Remember to factor in projected increases in energy costs, potential energy savings from lighting controls, replacement and disposal costs, and environmental impact.

Photo credit: AGI 32 and Radiance

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Emerging Technologies

Photovoltaic (PV) Systems

A photovoltaic (PV) system may serve as a stand-alone source or as a grid-connected source to remotely access a system's detailed energy-use profile, receive automatic maintenance alerts as soon as an issue occurs, and view or edit operating parameters via a desktop or laptop computer with the system software. Networked lighting control systems are another way to incorporate new features and improved technologies.

Networked lighting is a fundamental improvement in how lighting systems are controlled. With networked lighting, control of every light in a new space, maintenance issues can be quickly and precisely addressed, saving money and energy. Some benefits of networked lighting include:

- Remote monitoring and data assessment, including maintenance tracking and outage detection
- Demand response (DR) control
- Power sharing to take advantage of power savings from dimming
- Motion sensors with motion sensors for increased energy savings
- Easily adjustable light dimming profiles
- Scheduling, an alternative to photocell control

Networked Adaptive LED Wall Packs at UC Davis

In 2012, the University of California, Davis, upgraded 101 of its campus streetlights to networked adaptive LED fixtures. The campus selected full-cut-off, dimmable LED fixtures, controlled by a central server that monitors the lighting needs of the area, grouping connected systems together for more efficient incentives. For these reasons, grid-connected PV systems are becoming increasingly popular.

When a grid-connected PV system generates more power than the customer can use, the surplus power is fed to the utility grid. This is called net metering. Net metering is a common practice. When power exceeds what the system can produce, the customer draws electricity from the grid and is charged for electricity used.

Lighting loads installed underneath PV structures, such as solar-panelled canopies, should be minimized by pairing high-efficiency lighting with low-power PV panels.

Stand-alone PV systems are less common than grid-connected systems. These are not connected to the electrical grid; instead, they store energy in batteries, which are then used for power when the sun is not shining. Stand-alone PV systems incur additional initial costs and maintenance costs, and they must be connected to a battery.

Solar street and area lights can be used as stand-alone outdoor lighting applications where wiring, trenching, or metering is not feasible. These lights are often used in remote locations, such as in many locations on the luminaire – at the top, middle, bottom, or with the fixture pack underneath – and several options are available.

Additionally, PV ballasts are well suited for stand-alone systems. PV ballasts can be programmed to turn on at dusk and turn off at dawn. They can also be programmed to turn on when radio frequency power. Because there is no electrode, there is a common cause of failure for many HID lamps, plasma lamps, and systems that require high voltage and current.

Because of their high power density, plasma systems are currently being developed for outdoor lighting applications typical of those found in parks, playgrounds, parking lots, and outdoor sports facilities. With further improvements in validation, plasma lighting could potentially increase the energy efficiency of lighting in these outdoor applications.

More information on this project is available online: www.ies.org/codesandstandards/ies-10-speed-case-study-led-wall-packs.pdf

Photo credit: AGI 32 and Radiance

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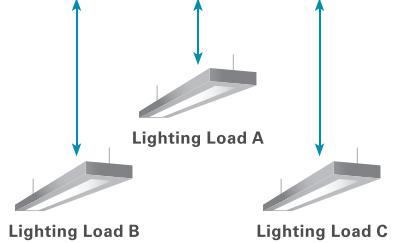
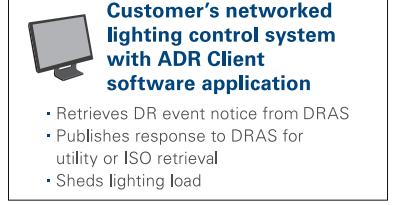
MODEL SERVER/CLIENT ENVIRONMENT FOR AUTOMATED DEMAND RESPONSE



INTERNET

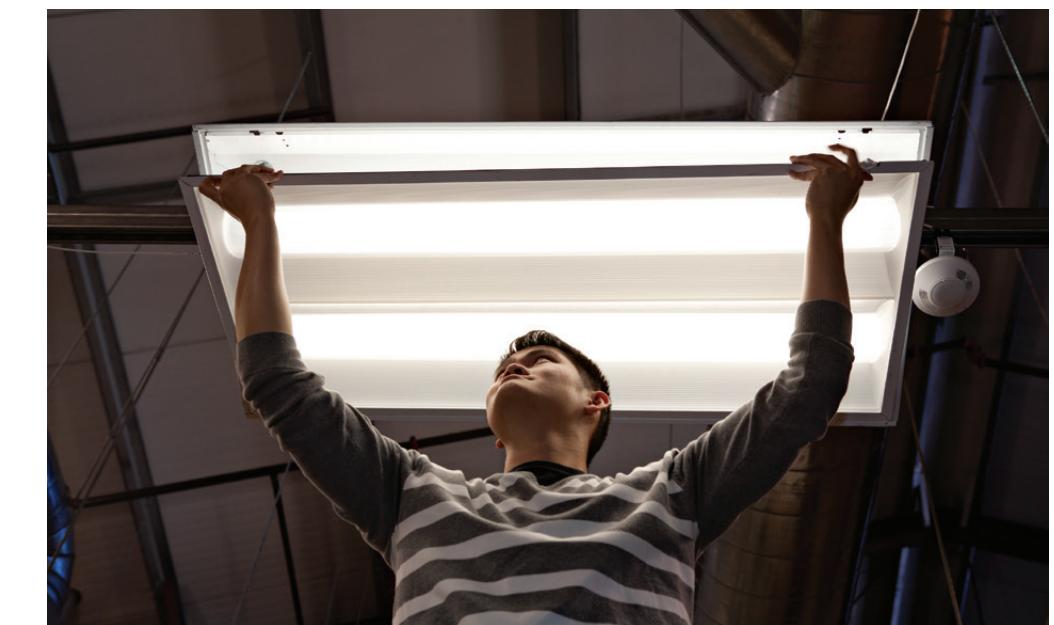
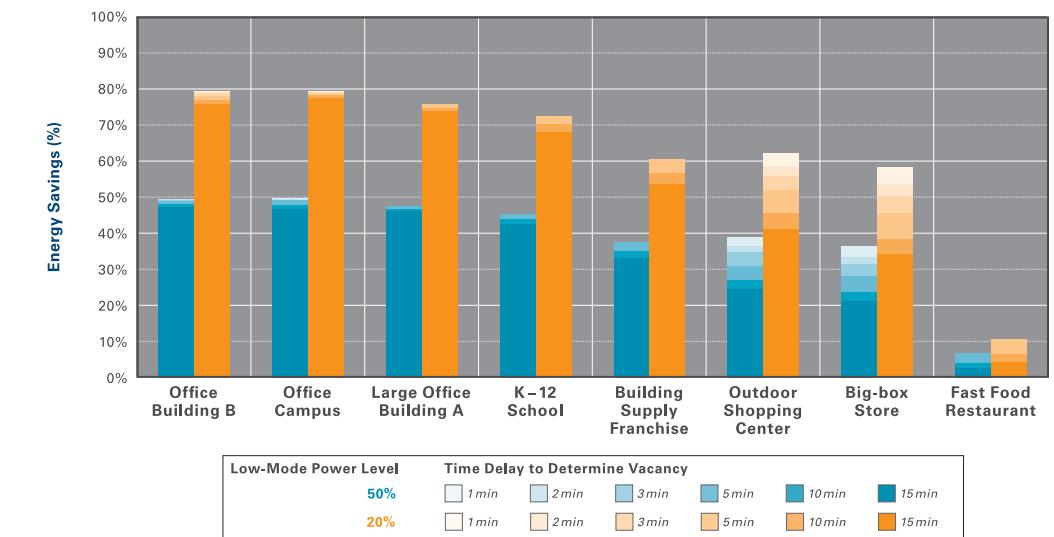
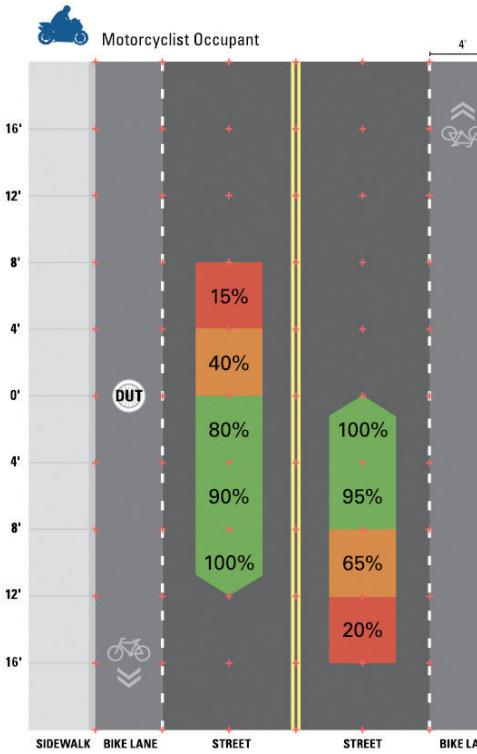
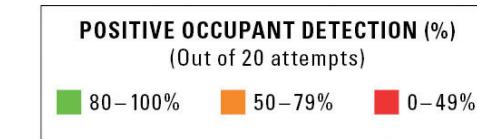
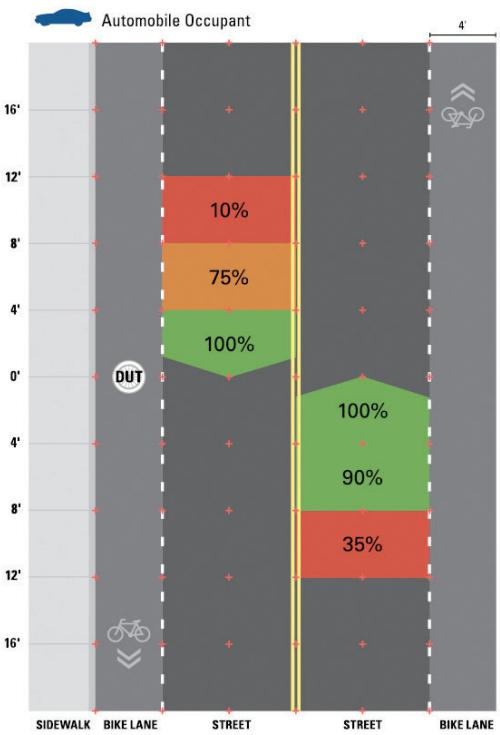


INTERNET



INTERNET

INDIVIDUAL SENSOR COVERAGE BY OCCUPANT TYPE

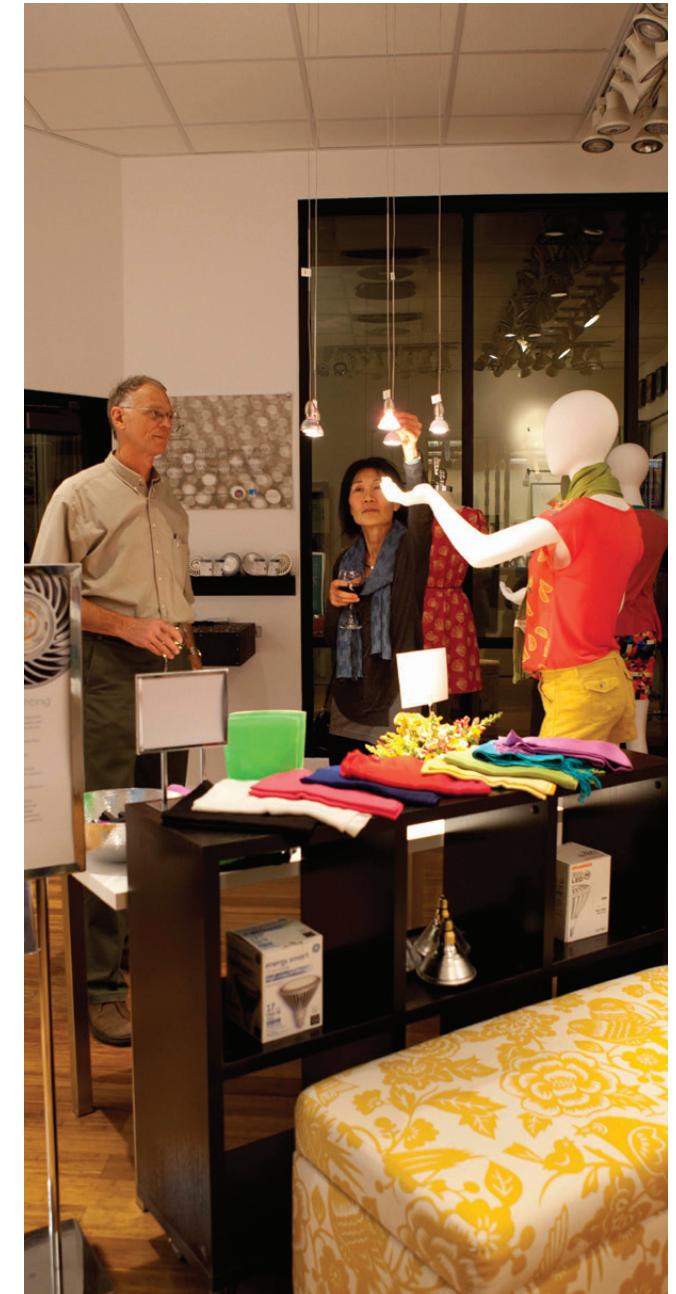


LD+A Research Column Article Graphics

Events



Celebrating a Decade of Innovation: CLTC 10-year Anniversary
2013







Smart Schools Symposium:
Energy Retrofits & New Funding Options

A one-day event to improve the efficiency and performance of California's K-12 and community college facilities

September 5, 2013
UC Davis Conference Center

Greenwise Joint Venture
Economy. Environment. Engagement.

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CALIFORNIA LIGHTING TECHNOLOGY CENTER

AcuityBrands



Smart Schools Symposium
2013



bringing **DAYLIGHT** *indoors*

Keynote Speaker:
LORNE WHITEHEAD, PHD
Professor of Applied Physics
University of British Columbia

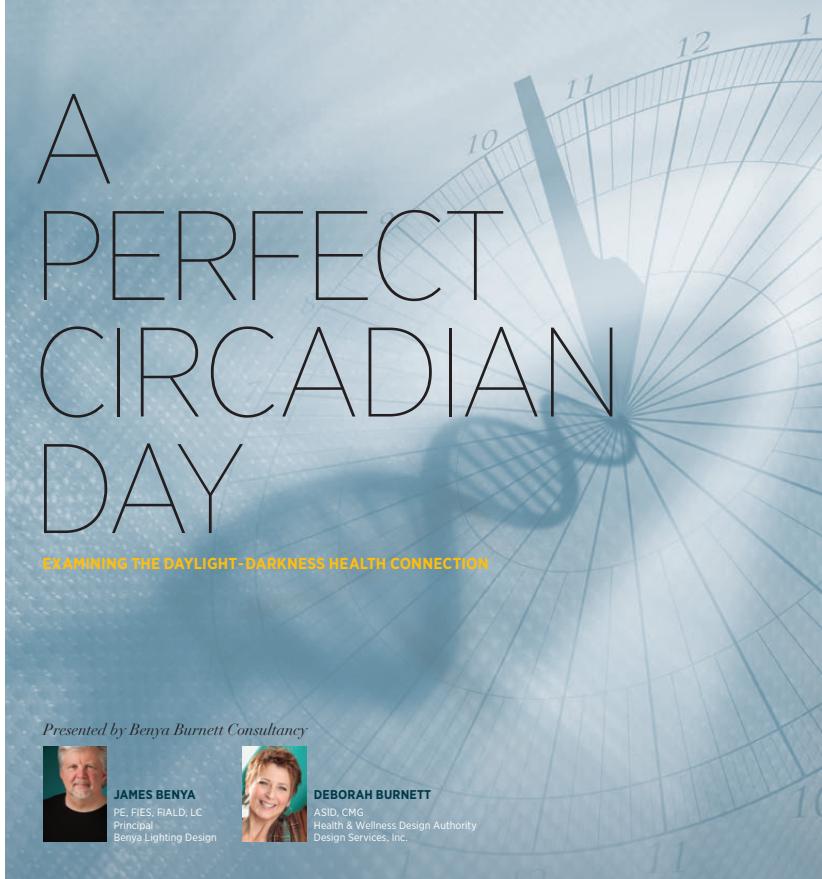
JANUARY 25, 2011 • 6–8 PM • UC DAVIS CONFERENCE CENTER BALLROOM
LECTURE ON EMERGING TOPICS IN ENERGY EFFICIENCY • OPEN TO THE PUBLIC

The Don Aumann Memorial Lecture in Lighting Efficiency series reflects the UC Davis and California Lighting Technology Center mission of sustainability through education and action.

This lecture series honors the memory of CLTC Program Director Don Aumann, and his visionary outlook in the field of energy efficiency.

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A PERFECT CIRCADIAN DAY

EXAMINING THE DAYLIGHT-DARKNESS HEALTH CONNECTION

Presented by Benya Burnett Consultancy

	JAMES BENYA PE, FIES, RIALD, LLC Principal Benya Lighting Design		DEBORAH BURNETT ASID, CMG Health & Wellness Design Authority Design Services, Inc.
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FEBRUARY 22, 2012 • 5:30–7PM • UC DAVIS CONFERENCE CENTER (BALLROOMS A & B)
LECTURE ON EMERGING TOPICS IN ENERGY EFFICIENCY • OPEN TO THE PUBLIC

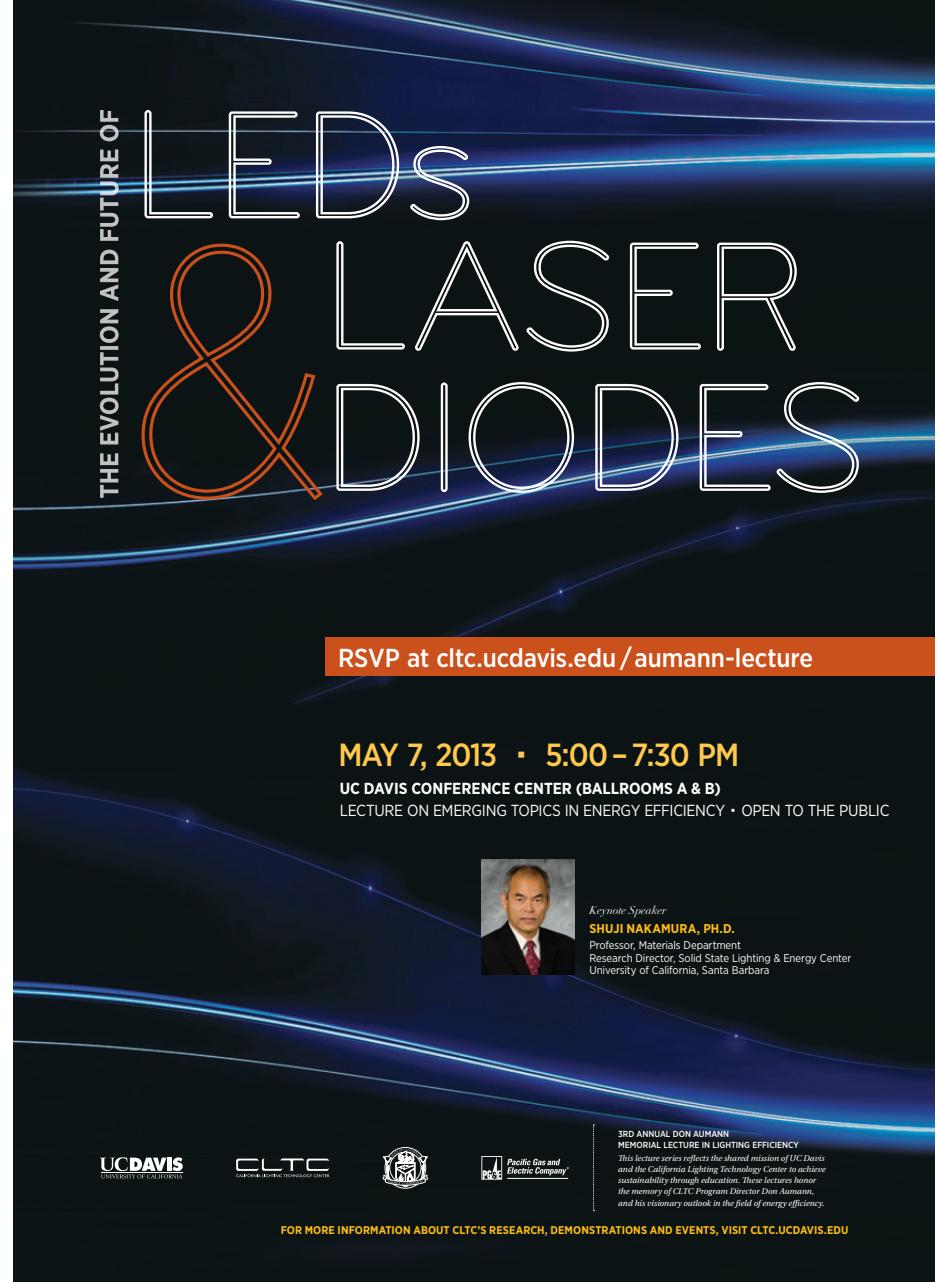
The Don Aumann Memorial Lecture in Lighting Efficiency reflects the shared mission of UC Davis and the California Lighting Technology Center to achieve sustainability through education.

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THE EVOLUTION AND FUTURE OF

LEDs & LASER DIODES

RSVP at cltc.ucdavis.edu/aumann-lecture

MAY 7, 2013 • 5:00 – 7:30 PM
UC DAVIS CONFERENCE CENTER (BALLROOMS A & B)
 LECTURE ON EMERGING TOPICS IN ENERGY EFFICIENCY • OPEN TO THE PUBLIC

Keynote Speaker
SHUJI NAKAMURA, PH.D.
Professor, Materials Department
Research Director, Solid State Lighting & Energy Center
University of California, Santa Barbara

3RD ANNUAL DON AUMANN MEMORIAL LECTURE IN LIGHTING EFFICIENCY
This lecture series reflects the shared mission of UC Davis and the California Lighting Technology Center to achieve sustainability through education.
This lecture series honors the memory of CLTC Program Director Don Aumann, and his visionary outlook in the field of energy efficiency.

FOR MORE INFORMATION ABOUT CLTC'S RESEARCH, DEMONSTRATIONS AND EVENTS, VISIT CLTC.UDAVIS.EDU

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Don Aumann Memorial Lectures in Energy Efficiency Series
2011–2013

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WHAT'S NEW IN THE 2016 CODE?**

ANNOUNCING CLTC'S LIGHTING BEST PRACTICES SERIES
Introducing CLTC's new What's New in the 2016 Code for Residential and Nonresidential guides.

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Accelerating the development and commercialization of energy-efficient lighting and daylighting technologies.
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UPCOMING EVENTS
OFFICE LIGHTING: TITLE 24 AND TECHNOLOGY UPDATE
05/16/2016
8:30 a.m. – 3:00 p.m. November, October 12 Energy Education Center - Irwindale 6090 N. Irwindale Ave. Irwindale, CA 91702 Instructor: Nicole Graeber
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RESIDENTIAL LIGHTING: TITLE 24 AND TECHNOLOGY UPDATE
05/17/2016
8:30 a.m. – 3:00 p.m. November, October 12 Energy Education Center - Irwindale 6090 N. Irwindale Ave. Irwindale, CA 91702 Instructor: Nicole Graeber
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Title 24 Building Energy Efficiency Standards

**2013 TITLE 24, PART 6
BUILDING ENERGY EFFICIENCY STANDARDS**



Abstract:
CLTC's Title 24, Part 6 resources are designed to help builders and lighting industry professionals become more familiar with California's Building Energy Efficiency Standards.

CLTC currently hosts training for the following applications:

- Residential Lighting
- Retail Lighting
- Office Lighting

The lighting portion of the 2013 Title 24 code incorporates technologies developed through CLTC's work with the Public Interest Energy Research (PIER) program and demonstrated through the State Partnership for Energy Efficient Demonstrations (SPEED). SPEED program demonstrations provided evidence of the effectiveness, feasibility and affordability of adaptive lighting technologies added to the new state codes and standards. CLTC is also involved in outreach and education efforts aimed at helping professionals meet—or exceed—Title 24 standards.

These resources are not intended to replace the Energy Commission's comprehensive Title 24 Building Energy Efficiency Standards or its compliance manuals. They are simply intended to help designers and building professionals become familiar with advanced lighting technologies and the latest code improvements.

Download the California Energy Commission's Title 24 standards and compliance manuals.

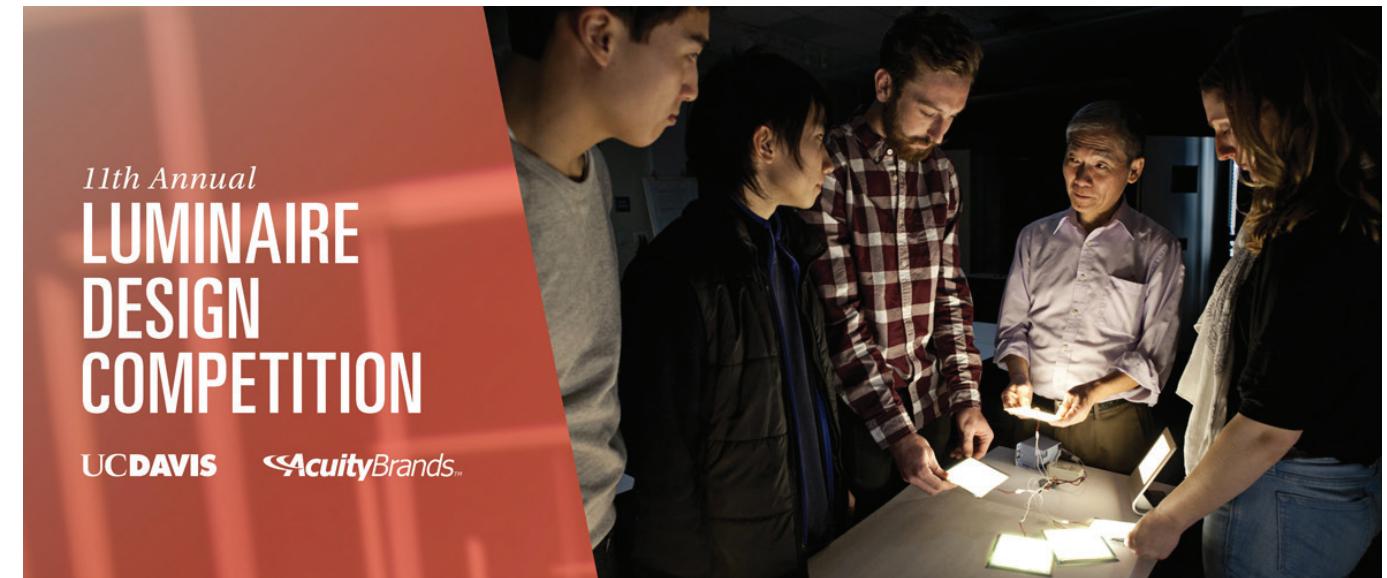
PROJECT CATEGORY
Advanced Controls Daylighting
Indoor Lighting Lighting Education
Outdoor Lighting
Policy, Codes & Standards

TAGS
California Quality Standards
Codes & Standards Commercial
Controls Education Indoor
LED Lighting Design Office
Outdoor PIER Policy

Guides

- Title 24, Part 6 Lighting for Office Applications Guide
- Title 24, Part 6 Retail Lighting Guide
- Title 24, Part 6 Outdoor Lighting Guide
- Title 24, Part 6 Residential Lighting Guide
- High Efficacy Residential Lighting Guide

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Exhibition & Trade Show



CLTC Demo Space & Signage



Fewer watts,
more lumens,
better value!

75%
off

ENERGY USE

The PAR 38 LED lamps installed in Lux use three-quarters less energy, on average, than 75-watt incandescents, and because LED lamps last up to 50 times longer than other sources, they also reduce maintenance costs.

DIRECTION & DISTRIBUTION

The atmosphere of a retail space is strongly influenced by the direction and distribution of light in the space. These aspects of lighting design also help to ensure visual comfort.



SPARKLE

LEDs can maximize the visual appeal of jewelry, gemstones, sequins, beading, glass, and metallic finishes, especially when used in a directional fixture.

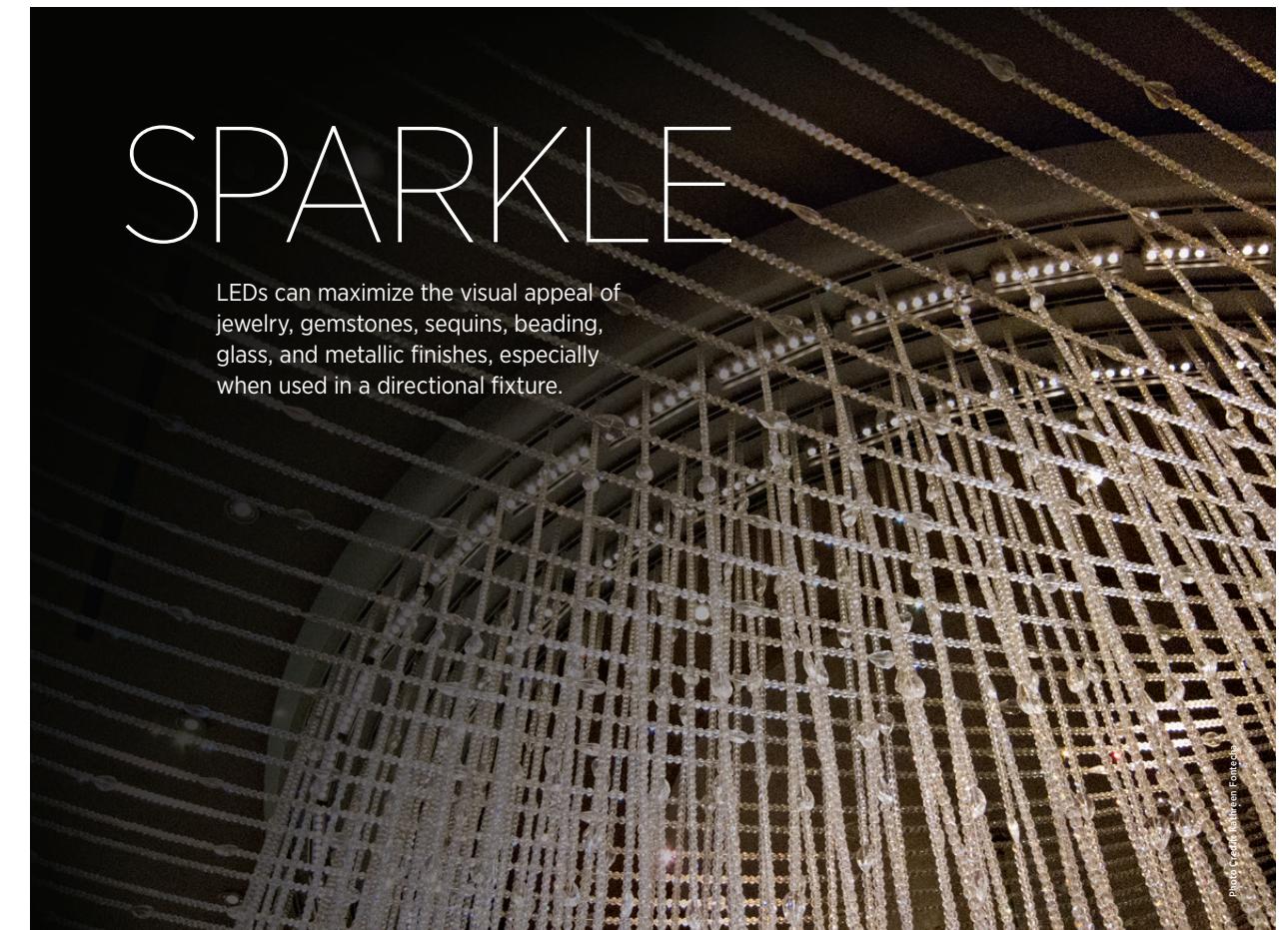
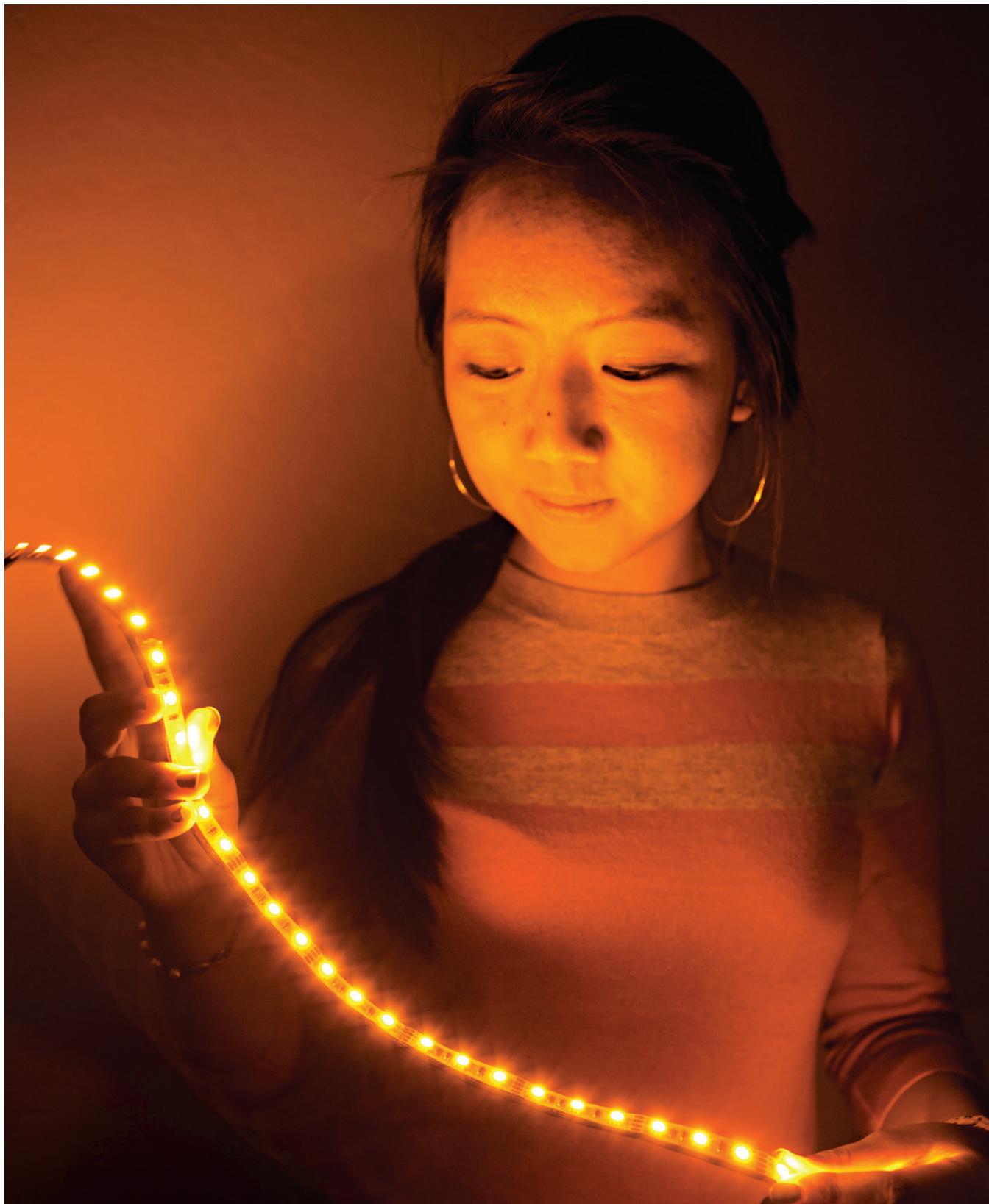
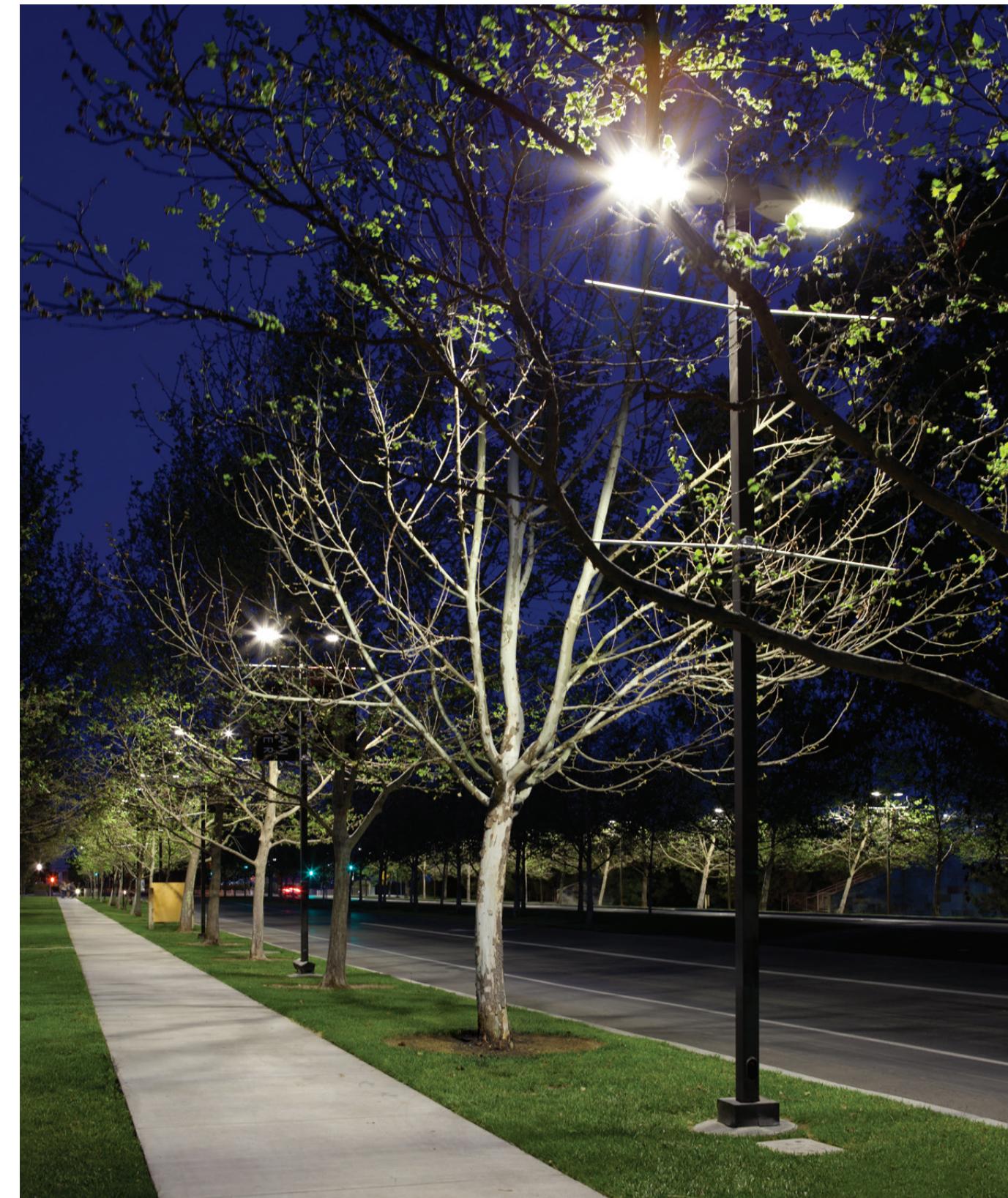


Photo Credit: Jason Porges



Both students and professionals form connections with research and industry leaders through classes, seminars, and forums that CLTC leads throughout the year. Undergraduate lighting courses are offered through the University of California, Davis, where students learn hands-on about lighting and daylighting technologies.

ONE SOURCE FOR LIGHTING EDUCATION
One UC DAVIS



Since its founding in 2003, CLTC has installed energy-efficient lighting technologies at over 100 sites on college campuses and in government buildings throughout California. These demonstrations, sponsored by the PIER Program, have saved California more than 6.1 million kWh and 6.2 million pounds of carbon emissions while reducing electricity costs by an estimated \$200 million each year.

ONE DECADE ADVANCING ENERGY EFFICIENCY
One UC DAVIS

LIGHTING CONTROL USER INTERFACE STANDARDS

USER INTERFACE STANDARDIZATION FOR THE PROMOTION OF ENERGY-EFFICIENT PRACTICES

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Lighting control user interface elements are governed by few standards. This may lead to products that are unnecessarily confusing for building occupants, leading to a lost opportunity for energy savings. The problem may worsen as control capabilities rise sharply with the advent of digital and networked systems.

The Lighting Control User Interface Standards project documented existing and emerging user interfaces for lighting controls and collected input from industry leaders and policymakers on the need for a lighting control user interface standard on selected elements, and a process by which to design and create it.

The project team concluded that standardizing selected elements would be accepted by the lighting industry.

SURVEY CLOUD SAMPLE



BACKGROUND

The Lighting Control User Interface Standards project is an initial investigation. Additional phases should follow that will conduct more detailed research, draw up possible content for one or more standards on the topic, and pursue adoption of those by appropriate organizations. The project was inspired by a California Energy Commission PIER project that saw final approval of an Institute for Electrical and Electronic Engineers standard.

The underlying proposition for both projects is the same: consistent user interfaces can improve usability of products and lead to energy savings. Consistency comes from standard elements of user interfaces, and the standards work best when they have the backing of a recognized standards organization. If the user perceives the room's lighting controls as overly complex or confusing, the likelihood of energy-efficient lighting use for the space may decline.

TECHNOLOGY AND RESEARCH APPROACH

The research team conducted a Survey of Existing Controls to collect, document, and analyze the common elements found in residential and commercial controls that the average occupant regularly comes into contact with.

The survey focused on the elements of common lighting control user interfaces, including switches, dimmers, and scene controllers found in homes and office spaces. Visual, tactile, and audio elements that serve as cues or feedback also were taken into account. The survey excluded control panels and software-based systems that are specific to facility and energy managers.

DEVICE INPUT & MOBILITY

Any lighting control interface that a user does not move regularly is considered fixed, even if the controller itself is wireless or movable under certain conditions. Any lighting control interface that the user moves on a regular basis as a part of the operation of the lighting in a space is considered mobile.



CONTROLLERS SURVEY



VERTICAL/HORIZONTAL MOVEMENT

INPUT	SWITCH	MECHANICAL INPUT	SLIDER	Mechanical Input	Hybrid Input	Digital Input	
INTERFACE	TOGGLE	ROCKER	DIMMER	TOUCH SLIDER	DIGITAL DIMMER CONTROLS		
MOVEMENT	Move toggle up/down	Move rocker up/down/right & left to change states	Drag node marking the current level of the system up & down/right & left to increase or decrease	Drag node marking the current level of the system up & down/right & left to increase or decrease	Top different intervals to jump levels	Drag node marking the current level of the system up & down/right & left to increase or decrease	
APPLICATION	On/off	On/off	Dimming, on/off	Dimming, on/off	Dimming, on/off	Dimming, on/off	
VISUAL CUES	TEXT On/Off TACTILE: Raised text	TACTILE: Raised rib, usually to signal the "on" state, click for on/off	TEXT On/Off TACTILE: Click for on/off VISUAL: On button and one older	TACTILE: Raised ribs indicating different levels VISUAL: Indicator lights for level	TEXT: Numbered different levels TACTILE: Click, spinning wheel showing different levels VISUAL: LED indicator for level	TEXT: Numbered different levels TACTILE: Click, spinning wheel showing different levels VISUAL: LED indicator for level	
POSITION / STATE	Two status locked at either on/off	Two status locked at either on/off	Slider position lockable from 5% (left) to 100%	Slider position lockable from 5% (left) to 100%	User can jump to different levels User can jump to different levels	User can jump to different levels User can jump to different levels	
FEEDBACK FOR STATE CHANGES	TACTILE: Mechanical click, perceptible to touch AUDITORY: Soft click	TACTILE: Mechanical click, perceptible to touch AUDITORY: Click	TACTILE: Mechanical click, perceptible to touch	VISUAL: LED indicators showing dimmer levels AUDITORY: Beep, click	TACTILE: For some interfaces, there is no tactile feedback. Some systems provide a small vibration or a slight change in the feel of the button to indicate that the user input was acknowledged. AUDITORY: Beep, click, or a short tone when the dimming is on. Other systems, especially mobile devices, do not have a reference point for a lower dimming level. In these cases, the response time is dependent on Internet speed and battery life. For example, a smartphone or tablet may take a long time to respond to a touch, while a laptop or desktop computer may respond almost immediately. VISUAL: LED indicators showing dimmer levels AUDITORY: Beep, click	TACTILE: For some interfaces, there is no tactile feedback. Some systems provide a small vibration or a slight change in the feel of the button to indicate that the user input was acknowledged. AUDITORY: Beep, click, or a short tone when the dimming is on. Other systems, especially mobile devices, do not have a reference point for a lower dimming level. In these cases, the response time is dependent on Internet speed and battery life. For example, a smartphone or tablet may take a long time to respond to a touch, while a laptop or desktop computer may respond almost immediately. VISUAL: LED indicators showing dimmer levels AUDITORY: Beep, click	
SYSTEM INDICATION OF ACTUATION	Light turn on/off The system indicates a history in this case, since it only allows for two states.	Light turn on/off The system indicates a history in this case, since it only allows for two states.	Light turn on/off Light level increases or decreases. However, a dimmed state might not be indicated. If the user does not have a reference point for a lower dimming level, the user can only guess what the light level is.	Light turn on/off Light level increases or decreases. However, a dimmed state might not be indicated. If the user does not have a reference point for a lower dimming level, the user can only guess what the light level is.	Light turn on/off Light level increases or decreases. However, a dimmed state might not be indicated. If the user does not have a reference point for a lower dimming level, the user can only guess what the light level is.	Light turn on/off Light level increases or decreases. White looking at the lights, a dimmer button, or a screen showing the light level. The user can only guess what the light level is.	Light turn on/off Light level increases or decreases. White looking at the lights, a dimmer button, or a screen showing the light level. The user can only guess what the light level is.

IN / OUT PUSH MOVEMENT

INPUT	SWITCH	Mechanical Input	Hybrid Input	Digital Input	
INTERFACE		SCENE CONTROLLER	TABLETOP TOUCH PANELCONTROLLER	WALLMOUNTED TOUCH PANEL CONTROLLER	
MOVEMENT			Push-button to change states or increase and decrease	Select "On/Off" or "Up/Down" to change states, select what aspect of the system to modify, or increase and decrease	
APPLICATION			Change states or set intervals (scene controller, dimming)	Change states or set intervals (scene controller, dimming)	
VISUAL CUES	TEXT On/Off POWER: numbered scenes, scene names (dependent on manufacturer naming convention) SYMBOL: Raised text	TEXT On/Off POWER: numbered scenes, scene names (dependent on manufacturer naming convention) SYMBOL: Raised ribs in highlight	TEXT On/Off POWER: numbered scenes, scene names (dependent on manufacturer naming convention) SYMBOL: State changes	TEXT On/Off POWER: numbered scenes, scene names (dependent on manufacturer naming convention) SYMBOL: Raised ribs in highlight	
POSITION / STATE			The physical interface of a fixture can be in one state—dimmed, off, or on—but it can also be in a different state—multiple buttons (combined with visual cue) can prompt the user to change the intensity between 5% and 100%, or to change states	Depending on the visual of the interface, there are often multiple buttons for each function, indicating user input is required	
FEEDBACK FOR STATE CHANGES			Multiple buttons (combined with visual cue) can prompt the user to change the intensity between 5% and 100%, or to change states	Depending on the visual of the interface, there are often multiple buttons for each function, indicating user input is required	
SYSTEM INDICATION OF ACTUATION			TACTILE: Button pressed down, tactile feeling of state change from rest to pressed down VISUAL: Indicating light showing power on/off AUDITORY: Tone, click	TACTILE: In some cases, vibration/change in state VISUAL: Light turning on/off, changing appearance (color, bolded text, highlighted) AUDITORY: Tone, click, or a short tone when the button is pressed. Depending on the visual of the interface, indicating that the user input is registered and the action has been taken AUDITORY: Tone, click, movement of a clicking hardware button	TACTILE: In some cases, vibration/change in state VISUAL: Light turning on/off, changing appearance (color, bolded text, highlighted) AUDITORY: Tone, click, or a short tone when the button is pressed. Depending on the visual of the interface, indicating that the user input is registered and the action has been taken AUDITORY: Tone, click, movement of a clicking hardware button

ROTATIONAL MOVEMENT

INPUT	SWITCH	Mechanical Input	Hybrid Input	Digital Input
INTERFACE		DIMMER	CIRCULAR DIAL REMOTE	
MOVEMENT			Rotate clockwise or counterclockwise to increase or decrease	Rotate clockwise or counterclockwise to increase or decrease
APPLICATION			Dimming (usually vertical channel)	Dimming (usually vertical channel)
VISUAL CUES	TEXT On/Off POWER: numbered scenes, scene names SYMBOL: Variability	TEXT On/Off POWER: numbered scenes, scene names SYMBOL: Raised ribs indicating different levels	TEXT On/Off POWER: numbered scenes, scene names SYMBOL: Variability	TEXT On/Off POWER: numbered scenes, scene names SYMBOL: Raised ribs indicating different levels
POSITION / STATE			Full rotation possible from 5% (left) to 100% Increases/decreases set intervals between 5% and 100% Dimmers often have the push functionality of a button for on/off	Full rotation possible from 5% (left) to 100% For hybrid inputs that are not rotary, there often is a set interval, which means the user can stop going to the next level until the user has a full 360-degree flexibility for movement. User can sometimes jump to different levels instead of gradually moving from 5% to 100%
FEEDBACK FOR STATE CHANGES			TACTILE: No tactile feedback AUDITORY: Tone (increases/increasing in volume), click	TACTILE: Monitor tactile feedback, although some systems do not have tactile feedback. Some systems provide a small vibration or a slight change in the feel of the button to indicate that the user input was acknowledged. AUDITORY: Tone (increases/increasing in volume), click
SYSTEM INDICATION OF ACTUATION			Light turn on/off Light level increases or decreases. However, a dimmed state might not be indicated. If the user does not have a reference point for a lower dimmed state to full light output. Color change for color-mixing systems For some interfaces, the interface does not include mechanical parts to change the levels, there are soft touch controls that are used to make the levels change.	Light turn on/off Light level increases or decreases. However, a dimmed state might not be indicated. If the user does not have a reference point for a lower dimmed state to full light output. Color change for color-mixing systems For some interfaces, the interface does not include mechanical parts to change the levels, there are soft touch controls that are used to make the levels change. The GUI of the system indicates which actions are active.

LIGHTING TAXONOMY

Audit of lighting controls in today's marketplace

Product images were collected and categorized based on whether they would be encountered by an end user or a professional energy/facility manager; interface complexity; mechanical or screen input; mobility; visual cues; and dynamic feedback elements. The collection was used to develop a taxonomy that represents the most common features of lighting control interfaces that are used in residential and commercial environments; the majority of the items surveyed can be found in either environment. The residential products serve as a baseline as they are typically less complex and sold at lower prices. The products were selected from 44 companies, including 28 lighting, eight home automation, three home improvement, two electric, and three others.

LIGHTING CONTROLS: FORMS & INTERACTIONS

Lighting controls include fixture-integrated switches/dimmers, wall-box switches, dimmers, programmable dimmers that control several scenes, and home automation systems that also control other systems (i.e., heat/air).

A controller that primarily turns a light on or off is a switch. A device used to control the intensity of light emitted by a luminaire is a dimmer. A unit capable of controlling multiple lamps, light settings, and/or lighting zones is a scene controller. A residential control system that also controls other systems is home automation. A handheld mobile lighting control device that the user moves on a regular basis is a remote.

STATIC ELEMENTS: VISUAL CUES

Visual elements assist occupants in understanding lighting control functions before touching the controller. Visual elements commonly include words, symbols, numbers, letters, and pictographs. The following graph shows the visual cue distribution from the survey.



DYNAMIC ELEMENTS: FEEDBACK & STATE CHANGES

Occupants receive feedback from lighting controllers via visual, tactile/haptic, and audio methods. The surveyed lighting user interfaces used a combination of these elements, although some interfaces did not employ visual cues beyond the positioning of the control on the wall in an area where a light switch commonly would be found.



Lightfair International 2014, CLTC & Seoul Semiconductor Booths
2010



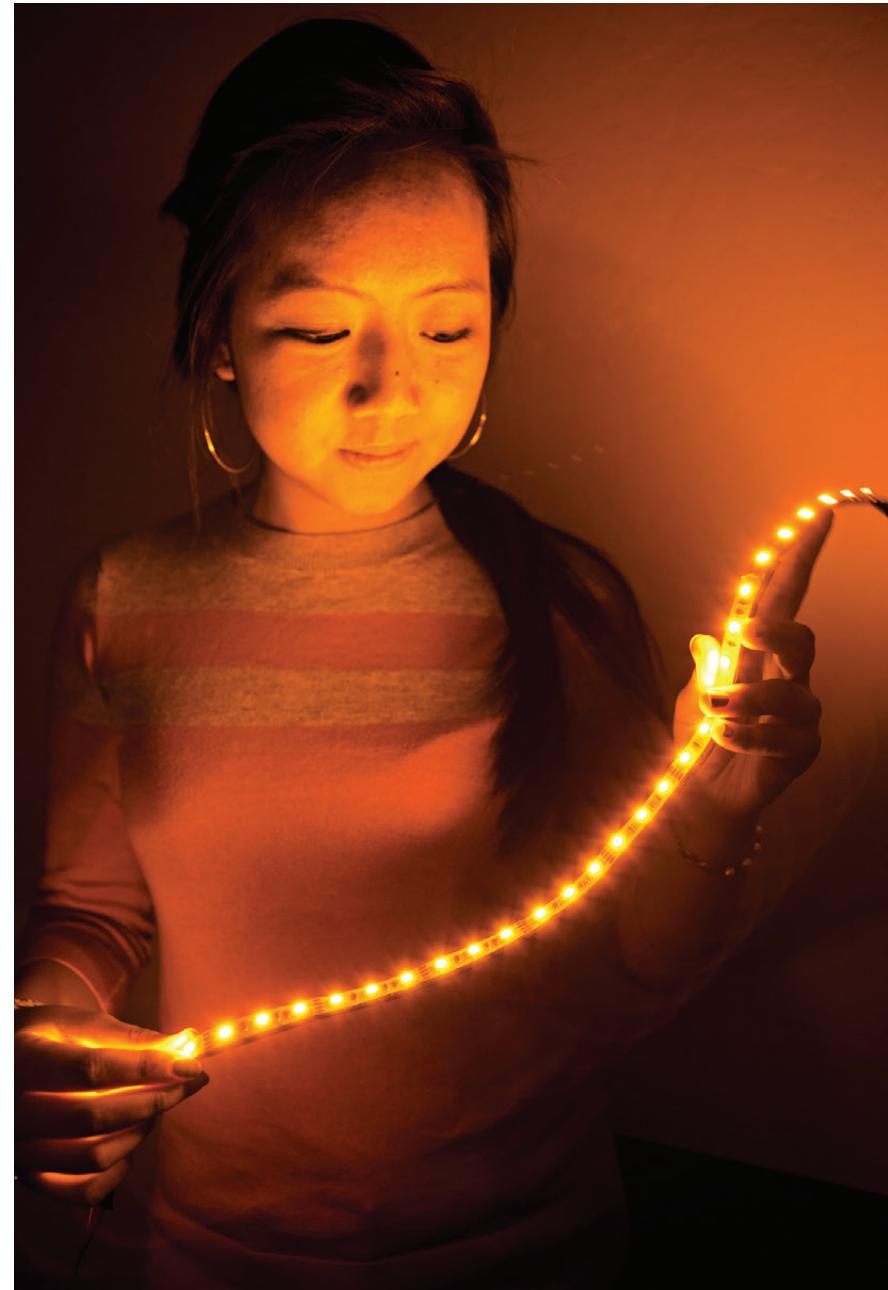
Chevron Center for Sustainable Energy Efficiency
2010



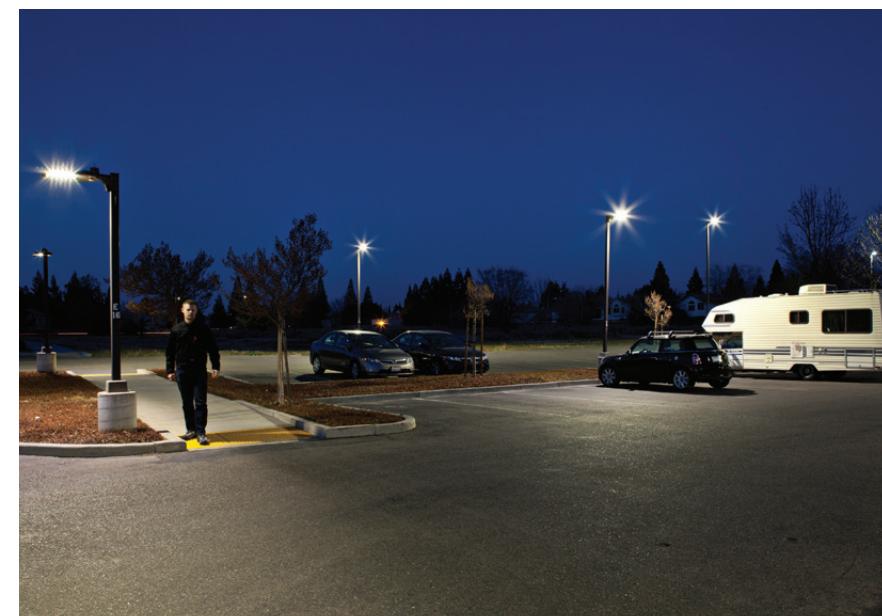
Propel Agile Networking Event

2016

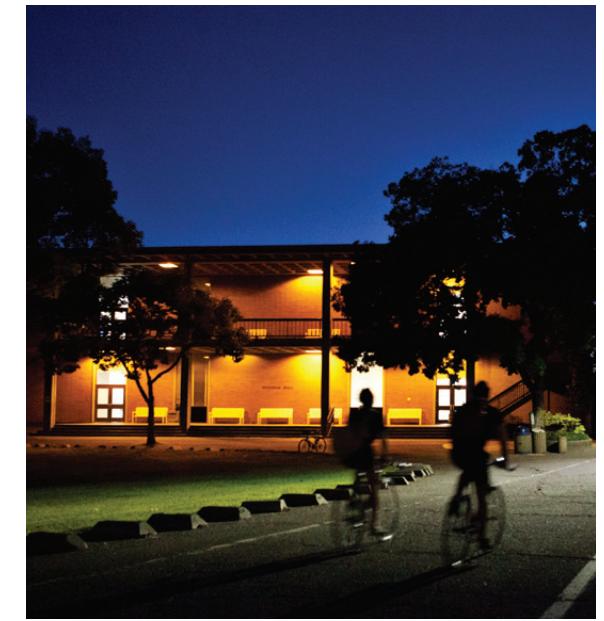
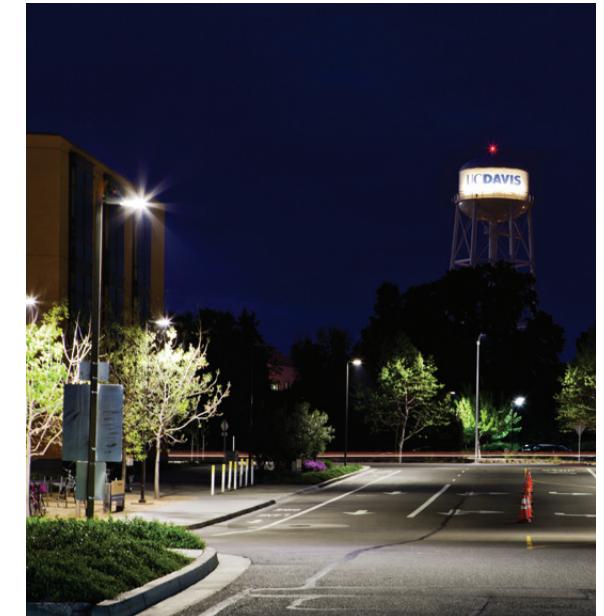
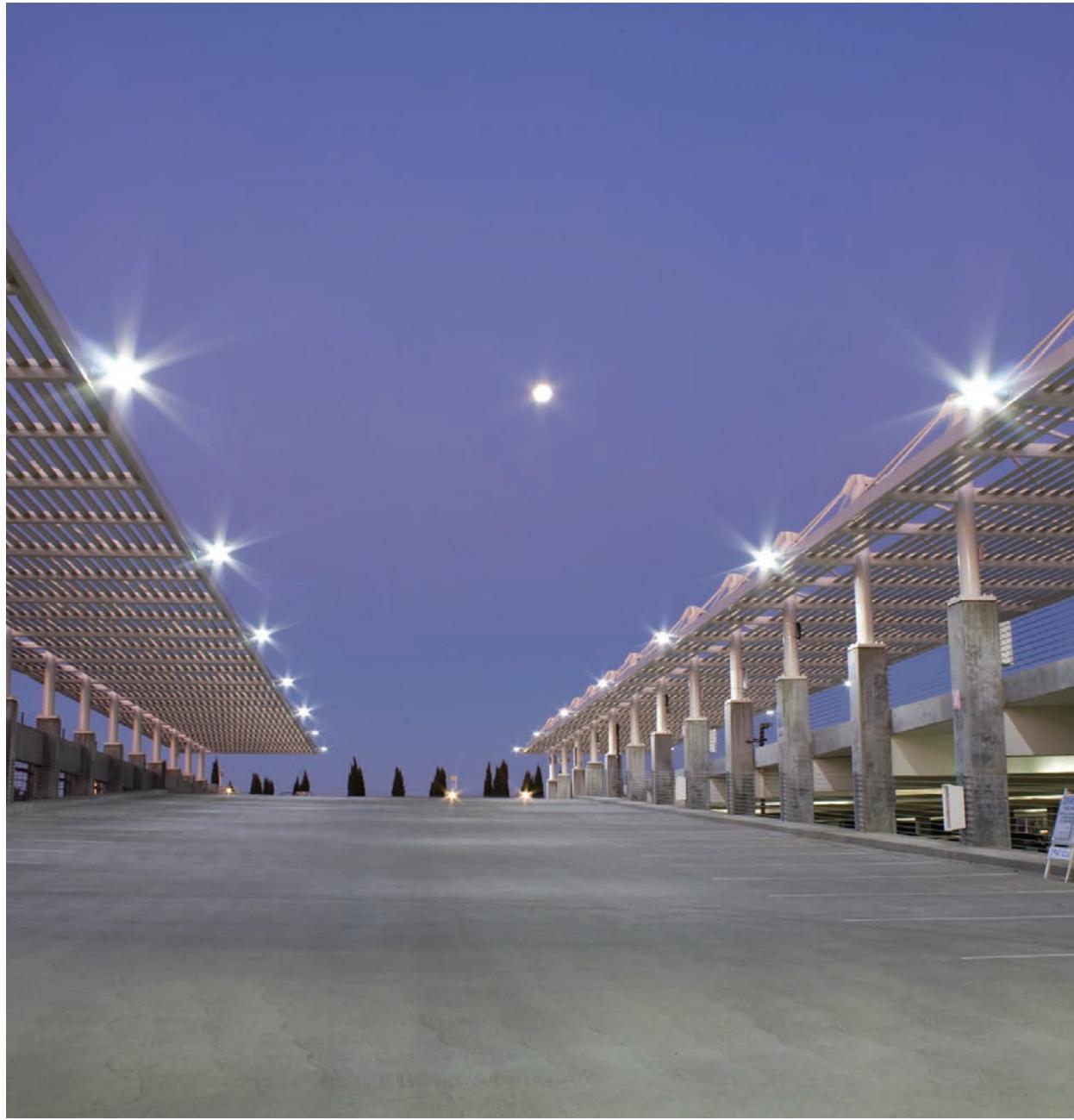
Photography



Lighting Design



Research & Demonstration



Exterior Lighting

