LIGHTING RETROFIT STRATEGIES FOR CALIFORNIA SCHOOLS

UC DAVIS
UNIVERSITY OF CALIFORNIA

DEVELOPED BY THE CALIFORNIA LIGHTING TECHNOLOGY CENTER (CLTC)
AT THE UNIVERSITY OF CALIFORNIA, DAVIS

This is an interactive document. For more information on products, case studies and resources, click on the photos or links provided.

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PHOTO: FINELITE INC; MICHAEL DAVID ROSE PHOTOGRAPHY

California's K – 12 schools spend an estimated $700 million total each year on energy expenses—about the same amount spent on books and supplies.

California Energy Commission Consumer Energy Center: Energy Tips for Schools

PHOTO: FINELITE INC.; FEINKNOPF/JASON MEYER

FOREWORD

California schools are currently in the process of a significant statewide upgrade of their mechanical and electrical systems. The objective is to achieve deep and lasting energy savings while improving the quality of the school environment. Funding from the California Clean Energy Jobs Act (Proposition 39) will greatly accelerate this retrofit process, and it presents a unique opportunity to achieve substantial savings and improve facilities.

Schools now face the significant challenge of identifying the best long-term strategies and supporting technologies to achieve energy savings in the most efficient and cost-effective manner possible. Schools will be confronted with a wide range of choices, with widely varying claims for energy savings and benefits. School facility managers and decision-makers will have to sort through sales presentations and technical literature from consultants and manufacturers on the latest and greatest opportunities to save energy.

To help address this need, the California Lighting Technology Center, at the University of California, Davis, has collaborated with its utility and industry partners to produce this concise, easy-to-follow lighting retrofit guide. This guide covers lighting and daylighting retrofit strategies that have consistently proven to provide the greatest long-term energy savings while maintaining, and often improving, lighting quality. These strategies and technologies have been tested and demonstrated on campuses throughout California.

Many of the key strategies presented in the guide will remain the same; however, the technologies that provide the foundation for these strategies will improve and change over time. For this reason, this guidebook is being developed as a living document that will be continuously updated to reflect this forward evolution. The guide will be organized and maintained as an electronic document. It will be constantly updated with new references and product information as new technologies emerge and new case studies are completed. The lighting guide will be maintained at the University of California, Davis, and updated links will be made available from our industry and utility partners.

Use this guide when working with consultants or contractors. Avoid retrofits that miss opportunities for deeper energy savings or sacrifice improved functionality and greater long-term benefits for limited, short-term gains, such as shorter payback periods. By focusing on lifecycle cost savings, school facility managers will make the most of this opportunity to invest in lasting, high-quality, long-term energy savings.

Professor Michael Siminovitch
UC Davis Rosenfeld Chair in Energy Efficiency
Director of the California Lighting Technology Center

PHOTO: CLTC, UC DAVIS

GETTING STARTED

As a school facility or project manager, you may take principal responsibility for lighting and daylighting retrofits, or you may be responsible for working with consultants or contractors in an oversight role for specific tasks. A typical lighting/daylighting retrofit project includes the following tasks, which involve the coordination of multiple consultants and contractors:

1. **Conduct an audit of the existing lighting and daylighting at your school**
2. **Prioritize retrofit applications according to the site's needs and project goals**
3. **Identify suitable strategies and technology options**
4. **Compare alternative retrofit options**
5. **Implement retrofit(s)**
6. **Measure and verify results**

The first step is to conduct an audit, or survey, of the school's existing lighting and daylighting portfolio. The audit will help you prioritize your retrofit process based on potential energy and cost savings, the ease and cost of retrofit options, and your school or district budget. This process often requires balancing efforts to maximize long-term energy savings against budget limitations. The resources section at the back of this guide includes agencies that provide auditing services to public and non-profit K – 12 schools. Utilities also offer financing, rebate and incentive programs for energy-efficient lighting and daylighting systems selected for retrofits and new construction.

List all the primary lighting applications at each site, and estimate the lighting energy used in each space. You can estimate this relatively easily by estimating the installed lighting power (wattage) and then the typical daily hours of use. Estimating hours of use is critically important, as energy use is a function of both installed lighting power and hours of operation. Hours of use often constitute the most important part of this equation.

Once you have completed your audit, you can begin to prioritize your opportunities for energy savings. Begin by ranking your opportunities based on the energy savings potential of each application and the ease of the retrofit process.

The best opportunities to reduce lighting energy use in schools are typically in spaces where lighting is not currently operating with any type of occupancy-based control system. Prime examples of these are restrooms, hallways, utility spaces, and outdoor lighting, including parking lots and building perimeters with wall packs. Many of these common applications are characterized by very long periods of operation with highly intermittent use patterns.

Identify these spaces that do not currently have occupancy-based sensor controls, and then rank them according to hours of use. The next step is to pair the appropriate commercially available, controls-ready luminaires with a sensor-based occupancy control package.

Another excellent opportunity to reduce lighting energy use and also improve lighting quality is through daylight harvesting in interior spaces, such as classrooms, gymnasiums and offices, where students, teachers and staff spend significant daytime hours. This strategy requires effective daylight penetration and distribution through windows and / or skylights, and electric lighting controls that automatically adjust electric lighting based on available daylight.

This guide offers insights on these specific strategies, examples of the technologies available to carry them out, and case studies of school retrofit projects, to help you, your contractor or your consultants move forward on a successful retrofit program.

When assessing and comparing solutions, it is important to examine the lifecycle costs and benefits of various options, and not just compare simple payback periods. Many times, lighting systems with longer payback periods yield much greater savings in the long term and provide a higher-quality environment. Be wary of consultants and contractors who advance an overly simplistic payback analysis or only offer retrofit options with low initial costs. Your school lighting retrofit is a long-term investment, and there is a tremendous opportunity to gain long-term energy savings through well-thought-out approaches.

Many of the retrofit strategies described in this guidebook require installation of advanced lighting control systems. It is very important that these controls are installed by contractors and electricians certified by the California Advanced Lighting Controls Training Program (CALCTP).

Work with your contractor to compare the energy savings potential, ease of installation, and the overall longevity of proposed retrofit options. With each retrofit approach, ensure that you have the opportunity to review technical literature and case studies of past installations. It is also often a good idea to pilot a new lighting or daylighting technology in a single space or site before deploying a large-scale retrofit. Pilot installations allow you to test and evaluate strategies and technologies before committing extended resources, and they provide opportunities to solicit feedback from faculty, staff and students.

Finally, once you have completed a series of retrofits, you should set up a measurement and verification (M&V) plan to quantify the savings achieved. If you are unable to undertake this, ask your consultant or contractors to provide you with a post-occupancy evaluation of the retrofit. Most installers will be happy to develop an estimate of savings after the job has been completed. This type of verification is often useful in helping identify successful approaches that you may wish to replicate in other parts of your facility or at other sites. Furthermore, savings measurements can be powerfully persuasive in garnering support from school board members and other decision makers. These measurements are often helpful, too — or even required — to secure grants or utility rebates that support continued retrofit activity.

Campus retrofit
The Met, Sacramento

PHOTO: STAFFORD KING WIESE

LIGHTING RETROFIT STRATEGIES FOR CALIFORNIA SCHOOLS

Review these recommended strategies with your contractor or consultants to help guide the retrofit decision-making process:

1. **Convert older T8 fluorescent luminaires to higher-efficacy light sources with dimming control**
2. **Convert all incandescent and CFL downlights to solid-state, LED technology**
3. **Consider window and/or skylight retrofits to increase daylight penetration in spaces with long hours of daytime use, such as classrooms, offices and gymnasiums**
4. **Install shading systems on windows and skylights to avoid glare and heat gain from direct sunlight penetration**
5. **Incorporate electric lighting controls for daylight harvesting in spaces where skylights or windows can provide enough daylight to meet required illumination levels**
6. **Choose high-reflectance materials for interior walls, ceilings and floors (such as white paint, ceiling panels and floor tiles)**
7. **Use occupancy-sensing controls in classrooms, offices, libraries, gymnasiums, restrooms, and other learning support spaces**
8. **Use occupancy-based, bi-level lighting in corridors, stairwells and other secondary spaces**
9. **Use occupancy-based, bi-level lighting for all outdoor parking areas, building perimeters (wall packs), and under-canopy walkway lighting**
10. **Integrate appropriate scheduling and / or photosensor controls for all outdoor lighting**

ELECTRIC LIGHTING

Strategies 1 and 2 are aimed at improving the luminous efficacy of electric light sources, i.e., the number of lumens per watt (lm/W) they produce. When selecting light sources, be sure to also address factors that influence lighting quality, such as correlated color temperature (CCT) and color rendering index (CRI).

CCT indicates the color of the light itself, ranging from yellowish white (2700 K) through white (3500–4000 K) to bluish white (5000 K or higher). While CCT choice is a matter of preference, higher CCT lighting will more closely match daylighting, and it supports circadian rhythms during daytime hours. If you are unsure about what CCT light to use, it is best to try out different light sources and involve the occupants of the space.

CRI indicates the ability of light sources to render colors of objects compared to daylight (for high CCT sources) and incandescent light (for low CCT sources). The highest CRI is 100, matching daylight and incandescent light. Most of the existing fluorescent lamps in your school probably have a CRI lower than 90, which distorts colors enough that most individuals can perceive the difference from daylight and incandescent lighting. Replacing indoor light sources offers a great opportunity to move to a higher CRI, of 90 or more. In outdoor spaces with bright nighttime illumination, you can use a lower CRI, of about 85, and in dimmer outdoor areas, you can go as low as 80.

DAYLIGHTING

Daylight harvesting (strategies 3–5) saves energy and reduces peak demand. It also provides high-quality lighting with excellent color rendering, and it benefits the health and wellness of students and staff who spend a significant number of daylight hours indoors. Strategy 3 improves daylight penetration while strategy 4 minimizes glare and unwanted heat gain by providing control over the amount of daylight admitted. Electric lighting controls (strategy 5) maximize the energy efficiency benefits of daylight harvesting. More detailed information on these key daylighting strategies is provided in the daylighting section later in this guide.

INTERIOR SURFACE REFLECTANCE

Strategy 6 applies to both daylighting and electric lighting. Choosing interior surfaces with a high diffuse reflectance spreads light throughout the space, and it is one of the most cost-effective modifications schools can make in conjunction with the lighting and daylighting retrofits recommended in this guide. Resurfacing walls, floors and ceilings (either with new paint or new panels or tiles) to have a high, diffuse surface reflectance makes interior spaces look brighter while equalizing brightness distributions and reducing glare.

LIGHTING CONTROLS

Strategies 5 and 10 are adaptive lighting strategies aimed at dimming or turning off electric lighting in indoor and outdoor spaces based on available daylight. Strategies 7, 8 and 9 reduce electric lighting through stepped or continuous dimming during vacancy and provide full light output during occupancy. Automated scheduling controls incorporated through energy management systems (EMS) can provide an additional layer of lighting control to maximize energy savings at schools.

All of the strategies and technologies described in this guide have been demonstrated in California. A variety of case studies on them, conducted at UC and CSU campuses, are available to the public through the cooperative efforts of the California Energy Commission, utilities, the lighting industry, and the California Lighting Technology Center (CLTC). The recommended strategies in this guide have also proven to achieve lasting and cost-effective energy savings, meaning that they will more than recoup their cost through energy savings over their expected service life. Many of these strategies have proven to be so reliable and cost-effective that they are now required under California's new 2013 Building Energy Efficiency Standards (Title 24, Part 6) for lighting, effective July 1, 2014.

These technology-neutral strategies are intended to serve as starting points in the development of larger retrofit project plans. More information is provided in the context of common school space types (classrooms, offices, hallways, etc.), focusing on major opportunities for energy savings through best-practice approaches.


PHOTO: EATON'S COOPER LIGHTING BUSINESS

CLASSROOMS, OFFICES & ADMINISTRATIVE SUPPORT SPACES

PRIMARY RECOMMENDATIONS

- Retrofit with dimmable, high-efficacy light sources or luminaires
- Install sensor-based occupancy/vacancy controls
- Maximize daylighting (window, skylight and shading system retrofits)
- Increase interior surface reflectance (with new paint, paneling or flooring)
- Include photosensor-based controls for daylight harvesting


PHOTO: LUTRON

Wireless lighting control systems eliminate the need for rewiring, making retrofits faster and easier.


PHOTO: CLTC, UC DAVIS

New LED luminaires with integrated sensors are available to replace recessed fluorescent luminaires.


PHOTO: GE LIGHTING

Suspended linear LED luminaires provide direct and indirect light, with dimming, in classrooms and offices.

General lighting in classrooms and office spaces is typically achieved with a regular array of recessed or surface-mounted 2 x 2 or 2 x 4 multi-lamp fluorescent luminaires or pendant-configured direct / indirect luminaires. These luminaires employ a variety of different types of T8 or T12 fluorescent lamps of various vintages. There are two main opportunities for significant savings and improvement through a lighting retrofit. The first is to use more efficacious light sources, including next-generation T8 or T5 fluorescent lamps or solid-state LED technology. Both options provide more light per unit of power consumed. The second opportunity is through use of lighting controls that adjust electric lighting based on occupancy and daylight levels.

Existing fluorescent luminaires present excellent opportunities to save energy through retrofits with new, higher-efficacy light sources and dimming control. The selection of specific retrofit technologies is a complicated decision involving a number of factors, such as the current condition of your existing fluorescent lighting, current power density, presence of lighting control systems, and economic considerations.

The following retrofit approaches are available today for existing linear fluorescent luminaires:

1. **Higher-efficacy T8 and T5 fluorescent lamps with dimming control.**
   If your current fluorescent luminaires are in good condition but use older T8 or T12 fluorescent lamps, it is recommended that you retrofit them with newer T8 or T5 fluorescent lamps and dimming electronic ballasts. Greater efficacy, combined with occupancy and daylighting control, will provide significant energy and cost savings. Additionally, if the existing lighting power density and light levels are high, you can use a lower ballast factor or make adjustments with your dimming electronic ballast to meet desired light levels. Changing T12 or older T8 lamps to newer T8 or T5 lamps will require new electronic dimming ballasts as well as some rewiring of the existing sockets (or "tombstones"). Many existing luminaires will need to be rewired to accommodate the typical programmed starting requirements of dimming electronic ballasts. It is extremely important to select lamps and dimming ballasts that are warrantied by the manufacturer for stepped or continuous dimming.

2. **Tubular LED lamps with dimming control.**
   High-quality tubular LED lamps (sometimes referred to as TLEDs) are an energy-efficient, solid-state lighting alternative to older T8 and T12 fluorescent lamps. Many TLEDs offer attractive payback periods; however, they warrant careful consideration with regard to safety, longevity and light quality. A tubular LED lamp retrofit should include a replacement or bypass of the existing fluorescent ballast with a dedicated, hardwired electronic driver that supports dimming control. This permanently and safely reconfigures the tombstones for an LED tube lamp. Additionally, you should test the resulting light distribution characteristics, as they may be significantly different from your original fluorescent lighting.

3. **LED replacement kits with dimming control.**
   LED retrofit kits provide the required electrical components, diffusers for glare control, and LED arrays in a prepackaged kit, allowing existing linear fluorescent luminaire housings to remain in place. Installation requires removing the existing fluorescent lamps and ballasts, leaving only the luminaire housing. This approach is particularly effective in installations where it may be difficult to remove the existing luminaire housing. This approach can provide a higher level of safety and performance than TLEDs at a similar or somewhat higher cost.

4. **New LED luminaires with dimming control.**
   This retrofit approach involves replacing existing fluorescent luminaires with new LED luminaires that have been designed specifically for operation with their solid-state light sources. This completely dedicated design offers the best opportunity for consistent and superior photometric performance, safety, longevity, and savings (energy and money). Retrofitting with an entirely new LED luminaire will most likely be the most expensive option in terms of initial project costs, but over the life of the product, the incremental cost associated with using new LED luminaires is actually very small compared to the lamp replacement and LED kit options.

54% ENERGY SAVINGS: 194,090 kWh and $17,500 saved annually

LANEY COLLEGE, OAKLAND

In 2011, Peralta Community College District installed a wireless integrated classroom lighting system (ICLS) in 39 classrooms at Laney College. Before the retrofit, instructors had just one switch that turned all the classroom lights either on or off. Now teachers can adjust lights for different activities. Integrated occupancy sensors and photosensors helped reduce lighting energy use 54% in the classrooms, based on an average occupancy rate of 30%.

▸ cltc.ucdavis.edu/publication/icls-laney-college

45% ENERGY SAVINGS $1,792 saved annually

MRAK HALL, UC DAVIS

A lamp-and-ballast retrofit of T8 fluorescent lighting improved lighting quality in the office and reduced lighting energy use 45%. T12 fluorescent undercabinet luminaires and incandescent desktop lamps were replaced with flexible, high-quality LED undercabinet lighting and Curve desk lamps by Finelite. Both task and ambient lighting feature wireless occupancy sensors.

▸ cltc.ucdavis.edu/publication/integrated-office-lighting-system-uc-davis

With fluorescent luminaires, the specific retrofit approach will depend on the condition of the existing luminaires and the opportunity for energy savings. In spaces where the existing fluorescent luminaires, operate at less than 1.5 watts per square foot and are already controlled by occupancy and daylighting sensor controls, there may be no substantial energy benefits and it may be best to focus on other retrofit opportunities that will likely yield greater energy savings. If your fluorescent luminaires are more than 10 years old and degraded, then you should strongly consider replacing them with new dimmable LED luminaires with occupancy and daylight harvesting controls. If your fluorescent luminaires are in reasonably good condition, then consider newer fluorescent lamps, TLEDs or LED retrofit kits, depending on your budget as well as your short-term and long-term energy efficiency plans.

Lighting controls significantly improve energy and cost savings, and they are required for compliance with 2013 Title 24, Part 6 standards in most school spaces. Project planners should select lighting solutions that are compatible with next-generation technologies for daylight harvesting, demand response and energy reporting. Systems that do not support digital control may have to be modified in the future, significantly reducing the potential of current retrofit opportunities.

Classrooms with skylights and/or windows present an excellent opportunity for daylight harvesting, whereby electric lighting is reduced or switched off during periods when daylight is available. This typically involves the integration of ceiling or luminaire-mounted photosensors and dimming drivers that are appropriately calibrated as a system, so electric light levels dynamically adjust to complement daylight levels. Daylight is most beneficial in classrooms and other learning spaces, and daylight harvesting works well with typical classroom lighting layouts to significantly reduce electric loads, while providing the best light quality. For more information on daylighting strategies and technologies please see the daylighting section of this guide.

CASE STUDIES & ADDITIONAL RESOURCES

College of the Desert Campus-wide Lighting Retrofit

▸ greenbuildings.berkeley.edu/pdfs/bp2011-collegeofthedesert.pdf

Incandescent and metal halide lamps were replaced with high-output T8 and T5 fluorescent lamps and high-efficiency ballasts. High-efficiency 25 W or 28 W T8s with a higher CCT (5000 K) replaced 32 W T8s in classrooms. Dual-technology (PIR / ultrasonic) occupancy sensors were installed for all classroom and office lighting. The energy management system (EMS) was upgraded and expanded to include all buildings addressed by the retrofit.
Best Practices Case Studies, Green Building Research Center, UC Berkeley, 2011

Del Mar Elementary School Daylighting Case Study

▸ calrecycle.ca.gov/publications/Documents/Schools%5C56005006.pdf

Six 21-inch light-gathering tubular skylights were added to five classrooms in San Luis Coastal Unified School District, virtually eliminating the use of fluorescent lighting in the classrooms.
California Integrated Waste Management Board, 2005

SeDoMoCha Elementary School Case Study

▸ leviton.com/OA_HTML/SectionDisplay.jsp?section=47636

This low-income school in central Maine reduced its electricity costs 50% with a daylight harvesting and occupancy-sensing lighting system for classrooms and offices (Leviton miniZ daylighting control and OSW12-M0W multi-technology occupancy sensor), as well as timed lighting controls in common spaces, including outdoor areas, and stand-alone lighting controls.
Leviton Manufacturing Co., Inc., 2007

UC Office of the President Integrated Office Lighting System Case Study

▸ cltc.ucdavis.edu/publication/integrated-office-lighting-system-uc-office-president

This demonstration of task-ambient lighting in private and open office spaces reduced annual energy use 44% at the UCOP building in Oakland. Standard 32W linear fluorescent lamps were replaced with super-saver 28W T8 ADV850 EW ALTO lamps by Philips. Task lighting consisted of 3W, 6W or 9W Curve LED desk lamps with personal occupancy sensors (part of Finelite's Personal Lighting System) and the Berkeley Lamp II by Full Spectrum Solutions. Simple payback was 3.8 years and lifecycle cost savings were estimated at 47%.
Public Interest Energy Research (PIER) Program, California Energy Commission, 2009

Pepperdine University Lighting Retrofit Project Overview

▸ lutron.com/en-US/Residential-Commercial-Solutions/Pages/SolApp/Education/College/PU/PepperdineUniversity.aspx

This Malibu campus tested then installed the Lutron Energi TriPak wireless lighting control system (with occupancy sensors, relay modules, and remote switches) in classrooms and offices. The retrofit has reduced lighting energy use 20–30%, and wirelessly integrating the classroom occupancy sensors with variable air volume (VAV) boxes has reduced HVAC energy use 14%.
Lutron Electronics Co., Inc., 2013

PHOTO: WATTSTOPPER

Ultrasonic, wall-switch occupancy sensors easily replace existing wall switches and provide reliable lighting control based on occupancy.

RESTROOMS

PRIMARY RECOMMENDATIONS

- Retrofit with dimmable, high-efficacy light sources or luminaires
- Install sensor-based occupancy/vacancy controls
- Increase interior surface reflectance (with new paint, paneling or flooring)

Restrooms with relatively new linear fluorescent luminaires paired with room-based occupancy sensor control should be considered low priority, as this lighting is already energy efficient. In restrooms with older vintages and single wall-based switches, the best strategy is to install higher-efficacy light sources, including T8 or T5 fluorescent luminaires, TLEDs, LED retrofit kits or new LED luminaires, in conjunction with room-based occupancy sensors.

Nearly all restrooms will yield outstanding energy savings with the introduction of occupancy sensors. This is because restrooms are typically unoccupied—with the lights left on—for more hours than they are occupied every day of the school year. Controls should turn off lights completely or dim them by at least 50% during vacancy, and time-out settings to determine vacancy should be adjusted to a minimum.

For school restrooms, dual-technology occupancy sensors that employ both passive infrared (PIR) and ultrasonic technologies will help ensure lights are not turned off or dimmed while occupants are behind stall doors or other objects. Adding wall-mounted occupancy sensors to school bathrooms may be the least expensive approach for lighting control in individual rooms. Wireless, ceiling-mounted sensors can also be placed over stalls to provide reliable coverage. The wireless unit communicates data to a wall box, which has been configured to control the existing circuit.

PHOTO: PHILIPS DAY-BRITE

Recessed LED luminaires with integrated sensors are an excellent choice to update fluorescent lighting.

UP TO 83% ENERGY SAVINGS

NATIONAL STUDY

A paper prepared for the Illuminating Engineering Society (IES) in 2000 found that installing occupancy sensors in public restrooms resulted in energy savings of 73–83%. The study looked at occupancy patterns in a cross-section of buildings in 24 states, including primary and secondary schools.

The same study found that reducing time-out settings on occupancy-based lighting controls was most effective in restrooms, where reducing auto-OFF time-out from 10–20 minutes to 1–5 minutes yielded greater energy and cost savings than in any other application.

▸ lrc.rpi.edu/resources/pdf/dorene1.pdf

Lighting controls
Comal School District, San Antonio, TX

LIBRARIES, STUDY HALLS & LEARNING SUPPORT SPACES

PRIMARY RECOMMENDATIONS

- Retrofit with dimmable, high-efficacy light sources or luminaires
- Install sensor-based occupancy/vacancy controls
- Maximize daylighting (window, skylight and shading system retrofits)
- Increase interior surface reflectance (with new paint, paneling or flooring)
- Include photosensor-based controls for daylight harvesting

Energy management systems can integrate scheduling, occupancy and daylight harvesting controls for optimal efficiency. They also track energy use and savings and make it easy to adjust lights remotely.

LED retrofit kits provide a safe, effective and efficient means to update fluorescent troffers to solid-state, LED technology.

Dimmable, controls-ready LED troffers are an excellent choice for new construction and retrofit projects.

TITLE 24, PART 6 REQUIREMENT FOR SECONDARY SPACES

Adaptive lighting is required in corridors, stairwells, and certain library book stack aisles, under California's 2013 Title 24, Part 6 standards. Lights should automatically dim by at least 50% of full lighting power when these spaces are vacant.

Lighting control systems that feature occupancy sensing, daylight harvesting and task tuning are compatible with LED, fluorescent and other types of luminaires.

Library lighting includes general lighting, typically provided by surface-mounted or recessed linear fluorescent luminaires, and task lighting, at workstations and over book stack aisles, often provided by fluorescent strip luminaires.

For older recessed or surface-mounted fluorescent luminaires that are in poor condition, consider installing solid-state LED technology, either using retrofit kits or new LED luminaires in conjunction with photosensor controls for daylight harvesting and room-based occupancy sensors. For luminaires in good shape, consider retrofitting with T8 or T5 lamps with dimming electronic ballasts, or solid-state technology such as TLEDs, LED retrofit kits or new LED luminaires.

Library book stack aisles are usually illuminated with linear fluorescent luminaires in series, controlled by manual switching or integrated with the existing overall library lighting circuit. When retrofitting the lighting for book stack aisles, you can achieve excellent energy savings with new bi-level LED strip luminaires that have integrated occupancy sensors. Controls can also be integrated using a system approach, with single occupancy sensors controlling multiple downstream luminaires in different aisles.

Daylight harvesting may also be an effective strategy for energy savings, depending on the arrangement of book stack aisles relative to windows and/or skylights. For more information on daylighting strategies and technologies, please see the daylighting section of this guide.

When selecting recessed LED ceiling luminaires, choose products that are dimmable and compatible with controls.

46% ENERGY SAVINGS $21,100 saved annually

PLEASANTON PUBLIC LIBRARY

In the summer of 2011, the Pleasanton Public Library (built in 1988) completed a building-wide lamp-and-ballast retrofit of its fluorescent lighting and installed a wireless lighting control system. Over the course of one month, the magnetic ballasts installed in the library's 32-watt, 2-lamp linear T8 fluorescent luminaires were replaced with dimmable electronic ballasts. New wireless controls incorporate daylight harvesting, occupancy sensing, scheduling, and tuning, reducing total lighting energy use by an estimated 36%. The luminaire retrofit was estimated to save another 10%, for total annual electricity savings of 46% and $21,100. The simple payback period for the project is 6.2 years.

- energy-solution.com/etap/wp-content/uploads/2012/05/ETAP_Pleasanton-WirelessLighting_CaseStudy.pdf

PHOTO: EATON'S COOPER LIGHTING BUSINESS

CASE STUDIES & ADDITIONAL RESOURCES

Colby College Miller Library Case Study

▸ leviton.com/OA_HTML/SectionDisplay.jsp?section=47636

Colby College, founded in 1813 in Waterville, Maine, had lighting on 24 hours a day in the book stacks of Miller library, with switches inaccessible for security purposes. Updating the system with occupancy sensors (Leviton 4-OSC10-M0W and 4-OSP20-0D0) dramatically reduced lighting energy use, saving the campus $6,472 every year.

Leviton Manufacturing Co., Inc., 2010

Woodcreek High School Theater Arts Building Lighting Retrofit

▸ roseville.ca.us/civicax/filebank/blobdload.aspx?BlobID=9089

Efficiency, function and maintenance were all improved with a lighting retrofit in the theater arts building at Woodcreek High School. Of the 49 incandescent flood lights that once needed frequent replacement, 43 are now long-life induction lamps. The new luminaires reduced energy use from 7.3 kW to 1.9 kW, virtually eliminated the precarious and time-consuming chore of lamp replacement, and provided two additional, brighter light level options in the space, allowing it to be used for lectures and classes in addition to performances.

Next-Generation Lighting Makes the Grade in Schools, Roseville Electric newsletter, 2006

UC Santa Cruz Science & Engineering Library Lighting Case Study

▸ greenbuildings.berkeley.edu/pdfs/bp2011-lighting-ucsc.pdf

UC Santa Cruz worked with Pacific Gas and Electric Company to reduce lighting energy use in the UCSC Science and Engineering Library 52%. In the reading area 265 66W can lights with magnetic ballasts were replaced with 111 39 W T5 volumetric 2x2 fluorescent luminaires. Wireless occupancy sensors were installed in various areas, including the library's book stack aisles, and wireless daylight sensors were installed in perimeter zones. A pilot installation of 2 x 2 LED luminaires in the computer lab was very well received.

Best Practices Case Studies, Green Building Research Center, UC Berkeley, 2011

Calvert High School Skylight Shading Case Study

▸ lutron.com/en-US/Residential-Commercial-Solutions/Documents/SolApp/Education/K12/CalvertHighSchool/3672373a_Clavert%20Case%20Study_Properties.pdf

Calvert High School in Maryland added a large, multi-use media center to its facilities with 35-foot skylights that span 17,000 square feet. The school selected wireless, automated controls and skylight shades by Lutron (Sivoia QS wireless roller shades). With five preset configurations, the school has been able to fully adjust daylight levels, minimizing its electricity use for lighting and reducing both cooling and heating costs.

Lutron Electronics Co., Inc., 2012

PHOTO: PACIFIC GAS AND ELECTRIC; LEWIS STEWART

GYMNASIUMS

PRIMARY RECOMMENDATIONS

- Retrofit with dimmable, high-efficacy light sources or luminaires
- Install sensor-based occupancy/vacancy controls
- Select multi-level lighting control for different functions
- Maximize daylighting (window, skylight and shading system retrofits)
- Increase interior surface reflectance (with new paint, paneling or flooring)
- Include photosensor-based controls for daylight harvesting

PHOTO: LUTRON

Wireless occupancy sensors can be installed in minutes, last for years, and provide thousands of dollars in annual electricity savings.

PHOTO: KENALL MANUFACTURING

Modular LED high-bay luminaires can match a wide range of light output levels, and they pair well with daylight and motion sensors.

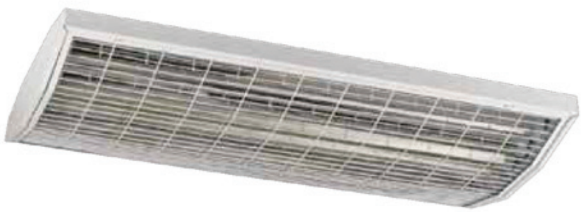


PHOTO: LUTRON

High-bay luminaires retrofitted with high-performance, multi-lamp T8 or T5 fluorescent lamps provide flexible enough to suit a variety of school and community events.

OVER 50% ENERGY SAVINGS
18-month payback period

CLOVIS UNIFIED SCHOOL DISTRICT

Beginning in 2010 Clovis Unified replaced the HID luminaires in 14 of its gyms with T5 fluorescent high-bay luminaires. The lights, which operate 18 hours per day, 363 days every year, were also equipped with Leviton passive infrared occupancy sensors. The retrofit dramatically improved lighting at all of the school sites, and energy savings exceeded 50%, reports District Energy Manager Stuart Ogren. The project payback period was just 18 months.

- pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/schoolsandcolleges/ctm-1209-0304_clovis.pdf

Gymnasiums predominantly employ high bay luminaires that have high lumen output and provide illumination for gymnasium activities, including video broadcasting. Static (single-level) high-intensity discharge (HID) light sources have traditionally served this purpose, including the very popular choice of metal halide (MH) lamps. Unfortunately, HID light sources have long startup cycles, making faculty and staff reluctant to turn lights off, even for long periods of inactivity. This re-strike issue has led to enormous waste in school gymnasiums with lights being left on for long periods of time.

Replacing old, static luminaires with dimmable, energy-efficient, "instant-on" luminaires will dramatically improve both the energy efficiency and functionality of your gymnasium lighting. Equip these luminaires with occupancy-based as well as manual controls that support multiple light levels to maximize energy savings while supporting lighting needs for different functions.

Installing new LED luminaires or LED retrofit kits with appropriate glare control is an excellent upgrade for most gymnasium lighting. Today's high-performance LED gymnasium luminaires typically come with controls integrated by the manufacturer or ready to accept the wide variety of different control scenarios available to support gymnasium lighting needs.

High-performance multi-lamp fluorescent and induction luminaires are two other energy-efficient source technologies that are suitable for gymnasiums. Multi-lamp linear fluorescent and induction lamps do a good job of matching the lumen output of traditional MH light sources. Both of these light sources should be installed with appropriate dimming ballasts that are also controlled through occupancy-sensing and astronomical time clocks.

Occupancy-based lighting controls can save significant amounts of energy in gymnasiums, which are often characterized by highly intermittent occupancy patterns. Integrated, occupancy-based lighting controls offer the largest opportunity for energy and cost savings. Integrate dimming or multi-level stepped lighting controls that include a lower light setting for periods of inactivity (to support safety) and additional settings to provide light levels for different activities, from morning cleaning tasks to televised nighttime games.

Many gymnasiums have good access to daylighting and present an excellent opportunity for daylight harvesting with the integration of appropriate photosensors that will turn off or reduce portions of the electric lighting when daylight levels are high. Maximizing the daylight potential in gymnasiums can offer excellent energy savings while providing excellent lighting quality. Top lighting through skylights and clerestories can provide excellent daylight illumination. Diffuse glazing can be very effective in such spaces, providing excellent quality with shadow-free illumination. Daylighting considerations will require planning with your consultant or contractor to identify appropriate spaces or zones within the gymnasium where electric lighting can be effectively reduced during daylight hours. Photosensor-based controls need to be appropriately commissioned to operate effectively and reliably.

Smart modules allow for easy integration of wired and wireless environmental sensors to make energy management easier and more effective.

PHOTO: LUTRON

CASE STUDIES & ADDITIONAL RESOURCES

Bryan High School Case Study

▸ leviton.com/OA_HTML/SectionDisplay.jsp?section=47636

This Ohio high school cut lighting energy use for its gym at least 50% by replacing its old HID luminaires with bi-level, double-ballast fluorescent lighting. High-bay occupancy sensors and Leviton EnOcean Lighting Controls provide manual-on / auto-off functionality and incorporate daylight harvesting, automated occupancy controls, and individual and master controls for seven zones in the gym.

Leviton Manufacturing Co., Inc., 2011

CSU Fullerton Titan Gym Wireless Lighting Case Study

▸ energy-solution.com/etap/wp-content/uploads/2012/05/ETAP_CSUFullerton-WirelessLighting_CaseStudy1.pdf

A retrofit completed in two weeks cut lighting energy use in the Titan Gym 66% and saved $11,700 in annual electricity costs. The HID lighting that once lit the gym was controlled by a single set of switches and operated an average of almost 16 hours a day, 7 days a week during the school year. Light levels were uneven, and the luminaires buzzed. CSU Fullerton replaced 68 400W metal halide luminaires, installing 68 216W 4-lamp T5HO F54 XtraLight luminaires, Lutron EcoSystem H Series dimming ballasts, and Lutron's Quantum Total Lighting Management system with occupancy sensors, wireless wall switches, control for each luminaire, and lighting management software. The lighting dims to 50% output after 10 minutes then gradually dims down to 10% of full output if the gym remains unoccupied.

Energy Upgrade California, Energy Solutions, 2012

Oakmont High School Lighting Retrofit

▸ roseville.ca.us/civicax/filebank/blobdload.aspx?BlobID=9089

Roseville Joint Union High Schools District improved both the efficiency and quality of lighting in the gym at Oakmont High School with a fluorescent luminaire upgrade. Twenty-four high-output T5 fluorescent luminaires replaced the 38 T12 fluorescent luminaires with magnetic ballasts that were previously installed. The retrofit not only reduced energy use from 12 kW to 8.5 kW; it more than doubled foot-candle measurements in the gym.

Next-Generation Lighting Makes the Grade in Schools, Roseville Electric newsletter, 2006

College of the Desert Case Study

▸ greenbuildings.berkeley.edu/pdfs/bp2011-collegeofthedesert.pdf

High-output T8 and T5 fluorescent luminaires with high-efficiency ballasts and dual-technology occupancy sensors replaced 400W metal halide and incandescent luminaires. The campus EMS was upgraded to enable manual peak load management and expanded to include all buildings in the retrofit.

Best Practices Case Studies, Green Building Research Center, UC Berkeley, 2011

T8 fluorescent troffers
Comal School District, San Antonio, TX

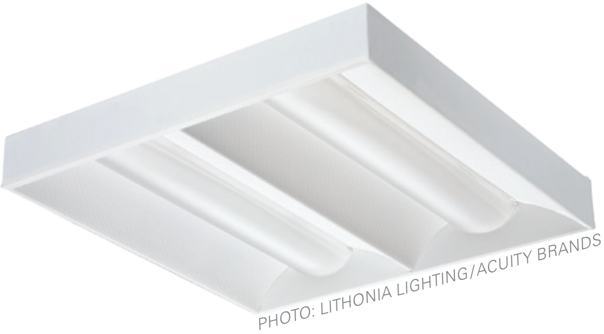
HALLS & ENTRYWAYS

PRIMARY RECOMMENDATIONS

- Retrofit with dimmable, high-efficacy light sources or luminaires
- Install sensor-based occupancy/vacancy controls
- Maximize daylighting (window, skylight and shading system retrofits)
- Increase interior surface reflectance (with new paint, paneling or flooring)

Linear LED luminaires with onboard occupancy and daylight sensors maximize the energy efficiency of hallway lights.

LED trim kits allow for easy replacement of Edison-base downlights.



Volumetric LED luminaires are controls-compatible and feature rugged construction.

Occupancy patterns in hallways and entryways are highly intermittent throughout the day, and these areas are largely unoccupied both during and after school hours. For these reasons, occupancy-based lighting controls have the potential to yield significant energy savings in these spaces.

Bi-level, occupancy-based lighting controls in corridors reduce lighting power during unoccupied periods by 50% or more and automatically restore full light output when occupants enter the space. This yields very large savings for educational institutions while maintaining safety, security and visual comfort.

Existing surface-mounted or recessed fluorescent luminaires that are in poor condition should be retrofitted with LED retrofit kits or replaced with new LED luminaires with integral controls. In both cases, the onboard driver should support dimming control based on occupancy sensors, and photosensors in daylit spaces. If the luminaire is in good condition, then recommended retrofit options include more efficient T8 fluorescent lamps, TLEDs, and LED retrofit kits.

All Edison-base downlights should be retrofitted with solid-state, LED technology. The best approach is to use LED trim kits. This involves removing existing incandescent lamps (A-, R- or PAR-lamps) as well as any of the existing finishing trims, and then installing new, finished LED trim kits that come prewired with an Edison-base whip, which is connected to the existing Edison socket within the recessed downlight can. The new trim kits snap into place in the existing recessed downlight. These trim kits are available in various directional distributions, so they can closely match existing incandescent lighting distributions. Such retrofits provide energy savings that can exceed 75%, as well as additional benefits of greatly increased life and reduced maintenance.

In 2013, CLTC published a business case study of various adaptive corridor lighting retrofits. It compared the costs and benefits of four different adaptive lighting control scenarios and found potential energy savings in the range of 70% to 86%. Adding occupancy sensors to existing T8 fluorescent luminaires reduced lighting energy use by 70%. The highest energy savings were produced by new LED luminaires with luminaire-integrated, occupancy-based networked controls. For all four corridor lighting control scenarios, calculations were made based on an occupancy rate of 20%.

73% ENERGY SAVINGS

BAINER HALL, UC DAVIS

Three corridor lighting retrofits carried out in Bainer Hall resulted in energy savings of 72–78%. Each demonstration used a different type of occupancy sensor: ultrasonic, microwave, and passive infrared (PIR). Savings measured were based on an average occupancy rate of 18% over a 24-hour period. Payback periods before utility incentives were estimated at 4.5–8 years.

▸ cltc.ucdavis.edu/adaptive-corridors

Adaptive corridor lighting can be achieved by installing appropriate light sources and controls that will accept sensor-based signals from either onboard or remote sensors. These technologies might consist of new T8 lamps and dimming electronic ballasts, TLED lamps with control-compatible drivers, LED retrofit kits, or new LED luminaires. Another common approach is to connect multiple luminaires to a centrally located occupancy sensor that is appropriately placed in the corridor. With this centralized sensor approach, it is important to make sure that the sensor has both the range and sensitivity for complete coverage of the space, which may require breaking up each corridor or hallway into discrete zones and commissioning controls for proper coverage and operation. Using a single sensor for each row or group of luminaires can reduce costs and may provide more uniform light changes than individual luminaires switching back and forth between low and high light levels.

Halls and entryways can also benefit by maximizing daylight potential. For more information on daylighting retrofits is in the daylighting section of this guide.

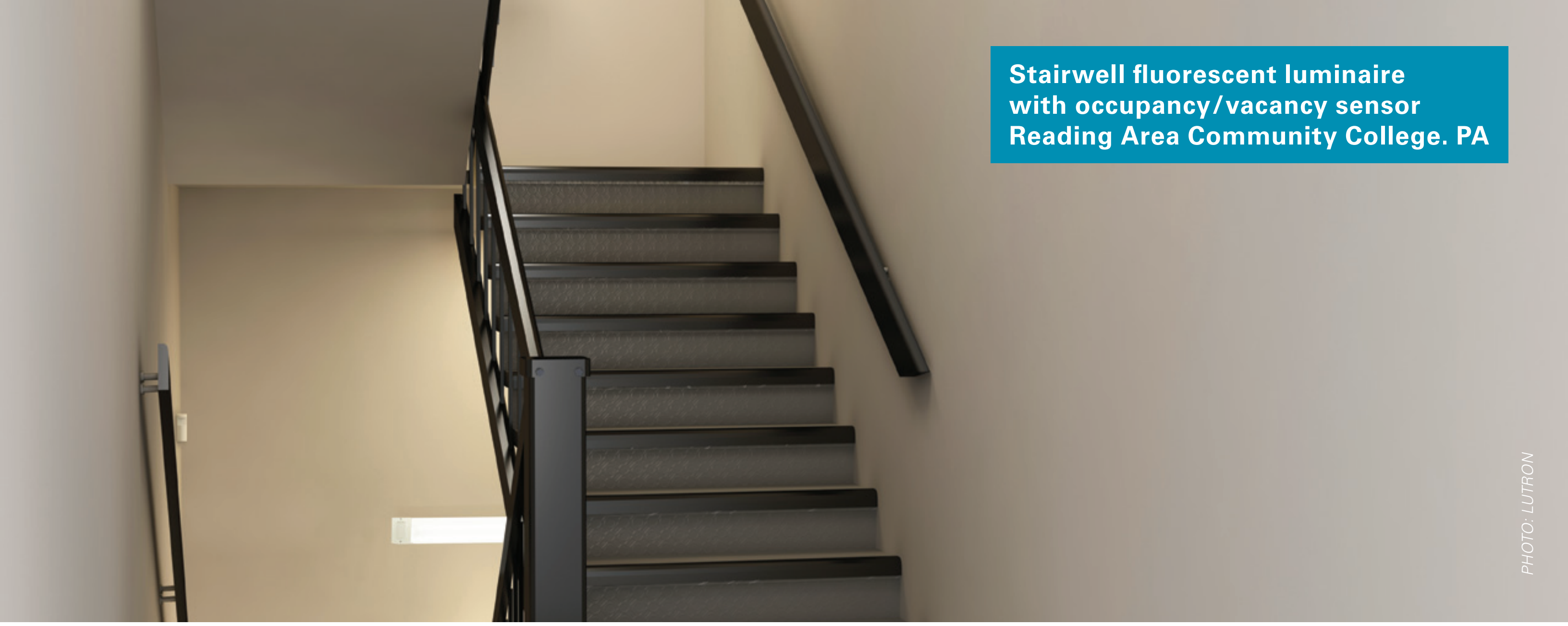
CASE STUDIES & ADDITIONAL RESOURCES

Smart Corridors Report: Bi-level Lighting

▸ cltc.ucdavis.edu/publication/sce-smart-corridors-bi-level-lighting-office-applications

Bi-level lighting systems reduced lighting energy use 46–65% in the corridors and stairwells monitored and evaluated for this report, significantly exceeding earlier calculations of 25–49%. In addition to field demonstration results, this report includes product guidelines and technology evaluations of various products, including adaptive corridor lighting technologies (Lutron H-Series T5 ballasts, wireless occupancy sensors and Energi Savr Wireless Control System).

Design & Engineering Services, Customer Service Business Unit, Southern California Edison, 2011



Stairwell fluorescent luminaire with occupancy/vacancy sensor Reading Area Community College. PA

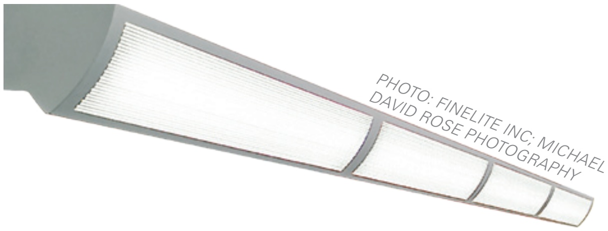
STAIRWELLS

PRIMARY RECOMMENDATIONS

- Retrofit with dimmable, high-efficacy light sources or luminaires
- Install occupancy-based controls that use sensors
- Maximize daylighting (window, skylight and shading system retrofits)
- Increase interior surface reflectance (with new paint, paneling or flooring)
- Include photosensor-based controls for daylight harvesting

Luminaire-integrated occupancy sensors that provide 360-degree coverage on either end ensure that occupants always have plenty of light when they need it.

Surface-mounted LED luminaires equipped with lumen maintenance, or lumen management, systems automatically adjust light output over the life of the luminaire, for more even light levels over a longer life.



Many LED luminaires suitable for use in stairwells can be specified with integrated occupancy sensors for maximum energy savings.

90% ENERGY SAVINGS

UNIVERSITY OF MINNESOTA

University of Minnesota reduced lighting energy use in its stairwells 90% with a switch from static T8, T12 and compact fluorescent sources to LED lighting with digital controls. The LED wall bracket and surface-mounted luminaires (W Series from Lithonia Lighting) feature integrated dual-technology occupancy sensors.

▸ acuitybrands.com/solutions/inspire-me/case-studies/university-of-minnesota-twin-cities

PHOTO: LITHONIA LIGHTING/ACUITY BRANDS

Typical stairwell lighting in schools includes either surface-mounted or recessed wall sconces that use CFL or linear T8 fluorescent lamps. These luminaires are often placed at each landing of the stairwell. The vast majority of these light sources operate all day, 7 days a week to maintain safety and security. Because stairwells typically have very low occupancy rates and highly intermittent use patterns, occupancy-based lighting controls can dramatically reduce lighting energy use in stairwells.

In compliance with 2013 Title 24, Part 6 requirements, lighting power for stairwell luminaires should be automatically reduced by at least 50% during vacant periods. At 50% power, general lighting is almost always well above minimum levels required for egress lighting. Recommended light levels should be restored when occupants are detected from either direction. A bi-level luminaire retrofit is easy to implement, has been demonstrated at numerous sites, and is proven to maintain safety and security.

If your current fluorescent luminaires are in good condition, a lamp-and-ballast retrofit in conjuction with adding an external sensor technology will provide bi-level function. Ultrasonic sensors typically offer a better level of detection in constricted stairwell configurations, compared to passive infrared (PIR) sensors, but PIR technology has proven effective when multiple sensors are integrated within the luminaire with different detection angles. In either case, ensure that the sensor technology is appropriately installed and commissioned for effective lighting control.

A TLED retrofit or LED retrofit kit that supports bi-level functionality is also a good choice. There is an evolving product base of bi-level LED luminaires with onboard sensors made specifically for this application. If luminaires are old and need replacing, the best long-term approach is to install new, dedicated LED strip luminaires with integrated dimming drivers that support bi-level light output. Installing new luminaires may be quite cost-effective in comparison to reconfiguring old luminaires.

Stairwells are often situated at the perimeter of buildings, where large glazed windows may present a significant opportunity for daylight harvesting with the integration of photosensor-based lighting controls. This requires careful placement of photosensors within the stairwell. Luminaire-integrated photosensors provide lighting control on a per-luminaire basis.

Alternatively, a single photosensor can be used to control multiple luminaires. Daylight harvesting systems are highly cost-effective, but like most lighting controls, they require careful installation and proper calibration to function properly. For more information about daylighting retrofits, read the Daylighting section of this guide.

CASE STUDIES & ADDITIONAL RESOURCES

Bi-level Stairwell Lighting Case Study

- partnershipdemonstrations.org/file_browser/speed/2%20Case%20Studies/2_2%20Interior%20Lighting/2_2_6%20Bilevel%20Stairwell%20Fixtures/uc_csu_stairwell_luminaire.pdf

Researchers replaced T8 and T12 fluorescent luminaires and incandescent lighting on several UC and CSU campuses with an adaptive (bi-level) stairwell luminaire by LaMar Lighting. The 2-lamp T8 fluorescent luminaire uses an ultrasonic occupancy sensor to dim lights to as low as 5% of full lighting power during vacant periods. Lighting energy use fell by an average of 62% (with occupancy rates of 1–10%), saving approximately $50 per year and resulting in a simple payback between 1–2 years. *California Energy Commission's Public Interest Energy Research Program, 2008*

Reading Area Community College Case Study

- lutron.com/en-US/Residential-Commercial-Solutions/Pages/SolApp/Education/College/racc

Reading Area Community College upgraded the lighting in 11 stairwells on its campus, installing a total of 110 luminaire retrofit kits and 60 occupancy sensors. Lighting operates at 60% when the space is occupied and 10% during vacant periods (in compliance with minimum Pennsylvania code requirements). Less frequented stairwells return to low-mode operation after one minute without an occupant detected. Five, 10 and 15-minute settings can also be selected, depending on use patterns. *Lutron, 2011*

DAYLIGHTING

Successful daylight harvesting requires three key considerations:

1. Daylight penetration through windows, skylights, and/or clerestories
2. Reflectance of interior surfaces, such as walls, ceilings, floors, and furniture
3. Electric lighting controls for daylight harvesting

The first step to daylighting consideration is to evaluate current daylight conditions in spaces where students, teachers and staff spend significant daytime hours. To evaluate the effectiveness of existing daylight conditions, experience the spaces under consideration during daytime with electric lighting switched off. It may be best to involve students, teachers and staff in this evaluation, which will make it faster and most effective.

If the daylight levels and distribution during daytime with electric lights switched off seems to provide all or most of the required light for the activities in the space, you are ready for photosensor-based electric lighting controls, described at the Electric Lighting Controls subsection. If the daylight levels seem low, then you should consider window and/or skylight retrofits and/or painting interior surfaces

WINDOWS & SKYLIGHTS

If daylight penetration seems to be limited by the existing windows and skylights (or lack thereof), rather than dark interior surfaces, check the window-to-wall ratio. It should not be less than 30–40%. Next, consider the transmittance of the glazing material in the windows and skylights. The visible transmittance should be at least 60%. If one or both of these conditions are not met, then window and/or skylight retrofits will likely be an excellent investment.

You can roughly assess glass transmittance by opening a window or door and comparing the brightness of light entering through these openings to that transmitted through the glazing of the closed windows and skylights. The higher the contrast, the lower the transmittance of the glass. You can also determine the transmittance of window glass by experiencing its reflectance, as high reflectance means low transmittance. To do this, look at the windows from outside of the building. If the reflection of outdoor objects is more visible than the interior surfaces, then the transmittance of the glass is low.

If the transmittance of the glass is low, but the window-to-wall ratio seems adequate, changing glazing or windows can greatly improve daylight penetration into the space. Before making a decision on window retrofits, you should consider retrofitting the space with skylights or tubular daylighting devices (TDDs), as this may be less expensive and will provide much better daylight distribution.

If the space does not have a ceiling, i.e., you can see the roof, consider skylights. In spaces with a ceiling, especially a grid ceiling with acoustic tiles, consider installing tubular daylighting devices (TDDs).

You can also use skylights in these spaces, but you will need to alter the ceiling and build skylight wells, which will probably be more expensive. Cost aside, the look and feel of skylights with wells is also very different from TDDs.

When considering window and/or skylight retrofits, look for options that include daylight management capabilities, such as shades and blinds, especially for windows facing east, west or south. Daylight management is most important for these orientations when there is no exterior shading through architectural elements, exterior window treatments or vegetation. If activities in the space include image projection, as is common in classrooms, consider window and skylight technologies that can minimize daylight penetration on demand.

Window treatments can also be integrated with electric lighting controls to optimize daylighting. These automatically adjust daylight penetration based on the status of the electric lighting. When daylight levels are sufficient to completely turn off electric lights, daylight management can limit further introduction of daylight, reducing the potential for glare and unwanted solar heat gain.

INTERIOR SURFACES

Daylight (and electric lighting) performance is greatly affected by the reflectance of interior surfaces, such as walls, ceilings, flooring, and furniture. Dark interior surfaces absorb light while lighter surfaces reflect light, increasing levels of illumination throughout the space. This increased reflectance reduces the contrast between daylight apertures and interior surfaces, greatly improving visual comfort.

If dark surfaces limit the effectiveness of daylighting, consider changing their reflectance by painting them with higher reflectance paint, preferably white, which reflects the whole daylight spectrum and maintains daylight's excellent color rendering properties. If you decide to increase the reflectance of interior surfaces, you should also consider a texture that diffuses the reflected light, to better spread the daylight (and electric lighting) throughout the space and minimize glare.

It is also helpful to make sure partitions do not block windows. Orient low partitions parallel to walls with windows and orient high partitions vertically, to help distribute daylight deeper into the space.

ELECTRIC LIGHTING CONTROLS

While conscientious occupants can save electric lighting energy with manual controls, you should consider installing automated controls that use photosensors to sense daylight levels and adjust the electric lighting accordingly. Make sure that the photosensor control technology is properly installed and commissioned, so it will operate correctly. Improper commissioning can result in over-dimming or under-dimming. Over-dimming of electric lighting will result in occupant complaints while under-dimming will reduce energy savings.

Traditional electric lighting controls for daylight harvesting use the signal of a single photosensor to control different groups of electric lighting luminaires. Newer systems use different photosensors for different groups of luminaires or even individual luminaires. Work with your lighting designer and/or contractor to determine what system is best for each application, so you can balance effectiveness with cost differential. Experience the controls after installation, and make sure occupants are satisfied with their operation.

Bi-level induction canopy luminaires
Lot 1, UC Davis

OUTDOOR LIGHTING:

Wall Packs, Parking & Canopy Lighting

PRIMARY RECOMMENDATIONS

- Retrofit with bi-level LED or induction light sources or luminaires
- Install sensor-based occupancy/vacancy controls
- Incorporate automatic scheduling controls
- Include photocontrols or astronomical time-switch controls
- Increase the surface reflectance of canopy ceilings (with paint or paneling)

Adaptive (bi-level) LED luminaires equipped with motion sensors provide efficient, long-lasting under-canopy lighting.

Adaptive (bi-level) LED wall packs reduce energy use over 50% compared to HPS or metal halide wall packs.

Adaptive (bi-level) induction luminaires are rated to last over 100,000 hours, and many come with five- or ten-year warranties.

Adaptive (bi-level) induction parking luminaires are available with integrated occupancy sensors and controls-ready ballasts.

The latest Title 24, Part 6 standards require that all outdoor lighting be equipped with automatic scheduling controls in addition to photocontrols (or astronomical time switches). Outdoor luminaires mounted up to 24 feet above the ground must also be equipped with motion sensors or another type of automatic lighting control system that will automatically reduce lighting power 40–80% when areas are unoccupied.

Outdoor lighting at schools typically involves the use of wall packs on exterior walls, pole-mounted high-pressure sodium (HPS) luminaires in parking lots, and canopy lighting configurations for parking areas and pathways. Significant savings can be achieved in these applications through the integration of adaptive controls, which reduce lighting power during inactive periods at night. This approach saves energy while maintaining safety, security and visual comfort. Integrating adaptive controls usually involves installing new luminaires with built-in sensors and controllers that support adaptive function.

BUILDING EXTERIORS

Exterior wall luminaires, or wall packs, provide nighttime lighting of building façades and school perimeters. Conventional thinking is that these wall packs provide a level of safety and improve security by deterring theft and vandalism.

Adaptive (bi-level) wall packs that dynamically adjust their output from 100% to 50% of full lighting power during periods of vacancy can provide significant energy savings without compromising safety, security or aesthetics. It is becoming broadly understood that sensor-based lighting technologies can also deter criminal activity and alert security personnel to after-hours activity on campuses.

Conventional wall packs predominantly use metal halide, HPS or compact fluorescent sources. To reduce energy waste and comply with the latest Title 24, Part 6 requirements, these luminaires can be retrofitted with systems that can achieve bi-level functionality based on occupancy. The best long-term approach would be to replace the existing wall packs with entirely new luminaires that have onboard motion sensors or are integrated with an appropriately located, centralized sensor.

Title 24, Part 6 also specifically requires that wall packs be equipped with photocontrols and automatic scheduling controls (or astronomical time switches) to prevent energy waste during daylight hours.

PHOTO: CLTC, UC DAVIS

89% ENERGY SAVINGS
74,841 kWh saved annually

UC DAVIS

In 2012 UC Davis replaced 101 HPS and metal halide wall packs on its campus with dimmable LED wall packs. System wattage for the old luminaires averaged 189 watts. The LED wall packs operate at 80% of full lighting power (or 45 W) during occupied nighttime periods and at 20% of full power (14 W) when no occupants are detected. Integrated daylight sensors automatically shut the wall packs off from sunrise to sunset. An advanced wireless lighting control system maximizes energy savings and allows facility managers to remotely monitor energy use, adjust lighting schedules, make real-time changes to individual luminaires or groups of luminaires, and receive automatic alerts when a maintenance issue arises. Over a six-week monitoring period, occupancy rates averaged 20%, resulting in energy savings of 89%.

▸ cltc.ucdavis.edu/publication/adaptive-led-wall-packs-uc-davis

CASE STUDIES & ADDITIONAL RESOURCES

Bi-level MH Wall Packs CSU Chico

▸ cltc.ucdavis.edu/publication/adaptive-hid-wall-packs-csu-chico

CSU Chico reduced the lighting energy use of 14 wall packs on its campus by 42% by upgrading from HPS to bi-level metal halide (MH) luminaires (NiteBrite wall packs by Philips Day-Brite). With integrated microwave occupancy sensors, the replacement wall packs automatically dim to 50% of full output during unoccupied periods.

Public Interest Energy Research (PIER) Program, California Energy Commission

Bi-level induction luminaires
Parking Lot 2, UC Davis

PHOTO: CLTC, UC DAVIS

PHOTO: CLTC, UC DAVIS

Network control systems can incorporate multiple types of outdoor luminaires into one radio frequency (RF) mesh network for easy monitoring and management.

PARKING LOTS

Most parking lot lighting in California schools consists of pole-mounted high-intensity discharge (HID) luminaires, typically high-pressure sodium (HPS) and, to a lesser extent, metal halide (MH) and fluorescent sources. These luminaires usually operate on a dusk-to-dawn schedule using a central time switch or photosensors. This prevents energy waste during daylight hours while maintaining safety and security at night. There is a significant opportunity to save energy during the evening and night, too, as long periods of inactivity during evening and nighttime are typical for school parking lots. Energy savings of 30–75% have consistently resulted from retrofit demonstrations that replace HPS lamps with LED, induction or ceramic metal halide sources and integrate adaptive, occupancy-based, bi-level controls.

Bi-level control technologies should reduce parking lot lighting power at least 50% during vacant periods and automatically increase light levels when occupants approach the area. This bi-level operation yields significant energy savings while preserving, or even enhancing, safety and security. Most bi-level parking lot luminaires available today include a light source, housing, control driver electronics, and a motion sensor that is either integrated or attached to the external body of the luminaire housing.

A standard retrofit approach would involve replacing HPS luminaires with bi-level luminaires that feature onboard sensors. There are many proven, cost-effective solutions available today that are easily installed in most parking lots. It is important to ensure that the luminaire supplier has integrated a high-quality occupancy sensor that maintains appropriate coverage in terms of sensitivity to occupancy and vacancy in the area.

71% ENERGY SAVINGS

CSU LONG BEACH

In 2011 CSU Long Beach hosted a pilot demonstration of adaptive parking lot luminaires. Three 189W metal halide parking lot luminaires were replaced with dimmable 67W ceramic metal halide luminaires. Each came pre-programmed to dim to 75% of full output for 10 hours each night. The retrofit yielded energy savings of 71%.

- cltc.ucdavis.edu/publication/curfew-dimming-parking-and-area-luminaires-csu-long-beach

An alternative approach is to group luminaires together and control them with strategically placed photosensors. In this case multiple luminaires would be hardwired or wirelessly connected to single sensors carefully positioned to provide full coverage of the entire illuminated area.

CASE STUDIES & ADDITIONAL RESOURCES

Yuba Community College District LED Retrofit

- energy.ca.gov/releases/2013_releases/2013-01-09_Yuba_nr.html

Yuba Community College District received a $900,000 loan from the California Energy Commission to implement energy-efficient lighting at its Yuba, Woodland and Clearlake campuses. The retrofit includes outdoor LED lighting for parking areas, pathways and canopies. Combined with interior fluorescent lighting retrofits, the project is expected to reduce energy use 64% and save $72,000 in annual energy costs.
California Energy Commission News Release, 2013

Loma Prieta Joint Union School District LED Retrofit

- energy.ca.gov/releases/2013_releases/2013-04-10_energy_loans_cities_schools_nr.html

This Los Gatos school district received an $85,000 grant from the California Energy Commission to retrofit its interior and exterior lighting, including several parking lots, with LED technology. The retrofit is expected to save $6,839 in annual energy costs.
California Energy Commission News Release, 2013

PARKING CANOPIES & COVERED PATHWAYS

Many schools have parking canopies or covered walkways that are often illuminated for long hours after the school is closed. The lighting installed underneath these structures typically consists of surface-mounted HPS, or multi-lamp fluorescent luminaires that operate at one level from dusk to dawn.

These canopy lighting applications are an excellent opportunity for significant savings with the addition of higher efficacy light sources operating with bi-level controls that reduce power to 50% during long periods of inactivity. A variety of new luminaire options are available that are highly cost-effective, energy-efficient, and easy to retrofit onto the existing electrical junction box (J box). These include LED, induction and multi-lamp weatherproof fluorescent luminaires that have built-in occupancy sensors and bi-level controllers.

Alternatively, centralized control through stand-alone occupancy sensors can be used to control multiple luminaires and can be easily retrofitted into existing canopies. It is important to ensure that the luminaire and control components you select include high-quality, weather proof sensors that provide the appropriate coverage for occupancy detection. The same type of adaptive lighting recommended for use under PV canopies can also be in similar outdoor structures, such as outdoor corridors and covered pathways.

CASE STUDIES & ADDITIONAL RESOURCES

South Entry Parking Structure, UC Davis

Adaptive LED luminaires (Cree, Inc. Edge) with integrated motion sensors provide under-canopy lighting on the top deck of UC Davis's South Entry parking structure. The bi-level luminaires reduce lighting energy use 50% when operating at full power and yield 80% energy savings when the space is vacant and the lights dim. The retrofit improved visibility, reduced light trespass, and made the installation virtually maintenance-free for 20 to 25 years.

PHOTO: CLTC, UC DAVIS

REDUCTIONS IN LIGHTING LOAD

WOODLAND JOINT UNIFIED SCHOOL DISTRICT

With support from SolarCity, Woodland Joint Unified School District (WJUSD) has implemented solar structures at ten different sites throughout the district. CLTC supported the district's selection of energy-efficient adaptive lighting for the solar-paneled carports at four of the sites.

The carports feature induction luminaires from EverLast Lighting equipped with motion sensors that adapt light levels to real-time needs, providing full light output when occupants approach and reducing lighting power when areas are vacant. The lighting controls are expected to reduce lighting energy use up to 50 percent.

"The pairing of solar canopies with adaptive lighting is a design standard at UC Davis and, now, at Woodland Unified," says CLTC Director Michael Siminovitch. "Hopefully, going forward, this will become the standard in K–12 schools across California."

The adaptive lighting strategy applied in this project emerged from PIER-funded research and development conducted through CLTC, beginning in 2006. The solution was demonstrated, proven effective, and adopted by UC Davis in a campus-wide lighting retrofit for parking lots and garages. This work provided evidence in support of California's 2013 Title 24, Part 6 requirements for lighting controls in outdoor area lighting and lighting in parking garages.

The solar-paneled structures provide more than 2,100 kilowatts of solar generating capacity, enough to offset 68 percent of energy use at the 10 sites where solar panels were installed.

- cltc.ucdavis.edu/article/wjusd-smart-lighting-solar-project

Bi-level LED canopy luminaires
South Entry Parking Structure Top Deck, UC Davis

PHOTO: CLTC; UC DAVIS

RESOURCES

There are many resources available for schools looking to retrofit their lighting. Some utility companies also offer rebate programs specifically designed to help schools fund projects focused on improving efficiency. Funding for qualifying energy efficiency upgrades may also be available through Proposition 39 funding.

BRIGHT SCHOOLS PROGRAM

energy.ca.gov/efficiency/brightschools

The Bright Schools Program offers services to help public and non-profit K–12 schools identify the most cost-effective energy saving opportunities at their facilities. Bright Schools can assist with energy audits and feasibility studies; review of existing proposals and designs; developing equipment performance specifications; comparing technologies; selecting contractors; reviewing equipment bid specifications; system commissioning; and funding recommendations.

CALIFORNIA ADVANCED LIGHTING CONTROLS TRAINING PROGRAM (CALCTP)

https://www.calctp.org/find-contractor

CALCTP educates, trains and certifies licensed electrical contractors and state-certified general electricians in the proper programming, testing, installation, commissioning, and maintenance of advanced lighting control systems. Trained and certified contractors are listed by city on the CALCTP website.

CALIFORNIA CONSERVATION CORPS (CCC)

ccc.ca.gov

CCC crews can conduct whole-building surveys to assess lighting and control systems, internal plug loads, HVAC, and building envelopes. They then share data with partners to arrive at project recommendations for each school. CCC can also perform work, such as installing lighting and occupancy detectors.

COLLABORATIVE FOR HIGH PERFORMANCE SCHOOLS (CHPS)

chps.net

CHPS is a non-profit organization that provides free resources, tools and trainings for schools and districts undertaking design, construction and retrofit projects.

CALIFORNIA ENERGY COMMISSION

energy.ca.gov/efficiency/proposition39
Prop 39 Hotline: 1-855-380-8722

energy.ca.gov/title24/2013standards
Energy Standards Hotline: (800) 772-3300

The California Energy Commission is working with the Department of Education, the California Conservation Corps, and other key stakeholders to implement the California Clean Energy Jobs Act (Proposition 39). These efforts direct funding and technical assistance to K–12 schools and community colleges for energy efficiency projects. Updates, information, trainings, forms, calculators, FAQs, and other resources are available on the Energy Commission's website. The 2013 Building Energy Efficiency Standards (Title 24, Part 6) are also available on the Energy Commission website.

CALIFORNIA LIGHTING TECHNOLOGY CENTER (CLTC)

cltc.ucdavis.edu/smart-schools-symposium-2013

Part of the University of California, Davis, CLTC is a not-for-profit research and development facility dedicated to advancing energy-efficient lighting and daylighting technologies. Presentations from the 2013 Smart Schools Symposium, information on new Title 24, Part 6 requirements for lighting, and other resources are available at CLTC's website.

ILLUMINATING ENGINEERING SOCIETY (IES)

ies.org

The IES is the foremost authority on lighting standards and best practices. Visit the IES website for resources, including a free pdf copy of Advanced Energy Design Guide for K–12 School Buildings (50%) and Recommended Practice for Daylighting Buildings (RP-5).

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

nema.org

NEMA develops standards and promotes safety and efficiency in the design, manufacture, installation, and use of electrical products. NEMA's Lighting Systems Division supports cooperative efforts to advance innovative and sustainable lighting practices. In pursuit of its mission, NEMA conducts educational forums and provides resources for its members and the public.

PRODUCTS FEATURED IN THIS GUIDE

CLASSROOMS, OFFICES & ADMINISTRATIVE SUPPORT SPACES

Iridium IQ by Corelite/Eaton's Cooper Lighting Business
cooperindustries.com/content/public/en/lighting/brands/corelite/suspended_iridium.html

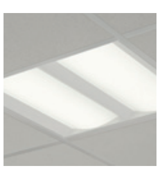
HPR-LED 2x4 with Sensor by Finelite
fineliteled.com/products/serieshprled-2x4-overview

Energi TriPak by Lutron
lutron.com/en-US/Products/Pages/SingleRoomControls/Energi_TriPak/Overview.aspx

Lumination LED Luminaire — EP Series by GE Lighting
gelighting.com/LightingWeb/na/solutions/lumination-ep-series.jsp

RESTROOMS

UW-100-24 Ultrasonic Low Voltage Wall Switch Sensor by WattStopper
wattstopper.com/products/sensors/wall-switch-occupancy-and-vacancy-sensors/uw-100-24



DuaLED 2x2 with Integrated Sensor by Philips Day-Brite
daybritelighting.com/day-britefluor/fluorfixture.cfm?ID=3584

LIBRARIES, STUDY HALLS & LEARNING SUPPORT SPACES

nLight Gateway by SensorSwitch
acuitybrands.com/products/detail/147305/sensor-switch/ngwy2/nlight-gateway-series-2

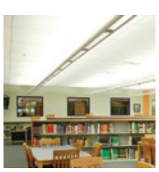
RTLEDRT Retrofit Kit by Acuity Brands
lithonia.com/commercial/rtledrt.html

Digital Lighting Management by WattStopper
wattstopper.com/products/digital-lighting-management

CR24 LED Troffer by Cree, Inc.
cree.com/Lighting/Products/Indoor/Troffers/CR-Series

Control System by Enlighted
enlightedinc.com/solutions/products

RLL14 Fixture and Retrofit Kit by Osram Sylvania
www.sylvania.com/en-us/products/new-products/Pages/OSRAM-RLL14-1x4-LED-Luminaires-and-Retrofit-Kits.aspx



Minigator by Corelite/Eaton's Cooper Lighting Business
cooperindustries.com/content/public/en/lighting/brands/corelite/suspended_minigator.html

GYMNASIUMS

EnviroPro by Kenall Manufacturing
kenall.com/Products/Product-Detail.htm?DataID=15279

Radio Powr Savr Wireless Occupancy / Vacancy Sensor by Lutron
lutron.com/en-US/Products/Pages/Sensors/Occupancy-Vacancy/WirelessRadioPowrSavr

Athlite by Lutron
lutron.com/en-US/Products/Pages/LightingFixtures/LutronFixtures/AthliteHighBayLuminare

EcoSystem by Lutron
lutron.com/en-US/Products/Pages/WholeBuildingSystems/EcoSystem

HALLWAYS, CORRIDORS & ENTRYWAYS

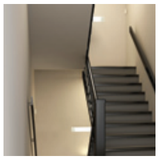
WRT by Lithonia Lighting / Acuity Brands
lithonia.com/commercial/wrt.html

LR6 by Cree, Inc.
cree.com/Lighting/Products/Indoor/Downlights-US/LR6-Series

RTLED by Lithonia Lighting / Acuity Brands
acuitybrands.com/products/detail/46989/lithonia-lighting/rtled/rt-series-volumetric-led-luminairel

CS Series by Cree, Inc.
cree.com/Lighting/Products/Indoor/High-Low-Bay/CS-Series

STAIRWELLS



Stairwell Fluorescent Luminaire by Lutron
lutron.com/en-US/Products/Pages/LightingFixtures/LutronFixtures/StairwellRetrofitFixture

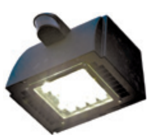
Aura by On-Q
http://onqlighting.com/index.php/parking/aura

WL Series by Lithonia Lighting/Acuity Brands
lithonia.com/commercial/wl.html

Series 17 LED Angled Curved Fascia (ACF) by Finelite Inc.
finelite.com/products/series17LED-ACF-overview

OUTDOOR LIGHTING

Edge by Cree, Inc.
cree.com/Lighting/Products/Outdoor/Flood/Cree-Edge-Series



WTM LED Wall Pack by Philips Day-Brite
daybrite.com/nitebrites/NiteBritesfixture.cfm?ID=3530

Mondavi Shoe Box Luminaire by EverLast Lighting
everlastlight.com/street-and-area-fixtures/mondavi-shoe-box.html

Classic Garage Luminaire by EverLast Lighting
everlastlight.com/outdoor-fixtures/classic-garage-fixture.html

Roadstar by Philips Lumec
lumec.com/products/luminaires/serie_roadstar.html

TOP-900 Wireless Control System by Lumewave
lumewave.com/products.html

For more information and resources about energy-efficient lighting and daylighting technologies, visit the CLTC website at ***cltc.ucdavis.edu***

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