NONRESIDENTIAL LIGHTING AND ELECTRICAL POWER DISTRIBUTION

A guide to meeting or exceeding
California's 2016 Building Energy Efficiency Standards

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NONRESIDENTIAL LIGHTING
& ELECTRICAL POWER DISTRIBUTION

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CHAPTER 1

INTRODUCTION

THE BENEFITS OF EFFICIENCY

Making nonresidential buildings more energy efficient reaps benefits including environmental and cost savings. The lighting requirements of California's Building Energy Efficiency Standards are aimed at reducing energy use while maintaining high-quality lighting.

Commercial buildings are one of the largest energy users in the United States. Today's commercial buildings consume 36 percent of U.S. energy, release 18 percent of carbon dioxide emissions and result in more than $190 billion in energy costs each year, according to the Department of Energy's Office of Energy Efficiency & Renewable Energy.

The potential to reduce energy consumption in existing commercial buildings is enormous. On average, 30 percent of the energy used in commercial buildings is wasted, according to the U.S. Environmental Protection Agency. Improving the energy efficiency of lighting systems has the largest potential for energy savings of any U.S. building end use. A significant fraction of that potential savings must come from inclusion of lighting controls, such as occupancy, daylighting, institutional tuning, automated demand response, and personal controls.[1]

[1] *Williams, Alison A., Barbara A. Atkinson, Karina Garbesi, and Francis M. Rubinstein. 2012. (Lawrence Berkeley National Laboratory). Quantifying National Energy Savings Potential of Lighting Controls in Commercial Buildings.*

Occupant Comfort

Factors to consider in commercial lighting design include human needs such as visibility, safety, and comfort; environmental and economic issues such as energy, equipment costs and sustainability; and how well the lighting complements the building design. A successful lighting design utilizes the right equipment to maximize visual comfort while reducing costs and a building's carbon footprint.

Market analysis indicates that companies with sustainability initiatives tend to profit more and perform better than competitors without these programs.[2] Sustainability programs are increasingly recognized as a source of innovation and a way to improve the appeal of a company or brand.[3] One path towards increased sustainability passes through the lighting environment. The design and installation of a highly efficient and long-life lighting system provides a high-profile, visual indicator of a company's commitment to energy efficiency.

Such a commitment can reap positive benefits with employees and clientele as well. For example, consumers have become increasingly concerned about their impact on the environment and aware of how their shopping habits affect the planet. Retailers have responded by increasing the sustainability of their products and business practices. Improving efficiency and reducing waste not only lowers overhead costs for building owners, but also provides an opportunity for business growth.[4]

LAYERS OF LIGHT

Adding task and accent lighting to ambient lighting allows ambient lighting loads to be reduced without compromising safety or visual comfort. In fact, this layered approach to lighting improves visual comfort by reducing contrast. Lighting designs that include task and accent lighting are also more attractive, as they provide variety and visual interest.

GENERAL AND PERSONAL LIGHTING CONTROLS

General lighting controls address an entire space or area. These controls are typically programmed to provide general purpose areas with energy efficient control strategies. For example, corridors equipped with occupancy sensors that enable bi-level lighting are one form of general lighting control.

Personal lighting controls address a sub-area and are typically associated with an individual's work station or task area. For example, lighting installed at a desk to provide illumination only on the desk plane is controlled separately from the overhead general lighting in place for the entire office. The personal and general lighting described above are examples of layers of light in a lighting design.

Health and Wellness

There is growing evidence indicating that the intensity and spectrum of light sources found in homes and workplaces have a significant impact on health and wellbeing. The spectral impact relates predominantly to hormonal imbalances on a diurnal basis, affecting our natural cycles or "circadian rhythms". Circadian-friendly design creates environments that resemble the intensity and spectral variations of light over the course of a day. During the daytime, access to daylight throughout the home or workplace also supports circadian wellness. Avoiding blue spectrum content at night is recommended to maintain appropriate melatonin production throughout the evening.

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[2] *2013 Retail Sustainability Report: Fueling Continuous Development, 2013, Retail Industry Leaders Association (RILA)*

[3] *The Innovation Bottom Line: Findings from the 2012 Sustainability & Innovation Global Executive Study and Research report, February 2013, MIT Sloan Management Review*

[4] *2013 Retail Sustainability Report: Fueling Continuous Development, 2013, Retail Industry Leaders Association (RILA)*

ABOUT THIS GUIDE

This is one of seven guides designed to help builders, designers, contractors, and others involved in the compliance process become more familiar with California's 2016 Building Energy Efficiency Standards. It is designed to serve as a resource for industry professionals involved in the design, construction, or retrofit of California's buildings. The guides include compliance requirements and recommendations for implementing the Energy Standards in new construction, addition or renovation projects.

All seven guides can be found on the **Energy Code Ace website:** EnergyCodeAce.com

Application Guide	What's Covered
NONRESIDENTIAL ENVELOPE & SOLAR-READY AREAS	• Climate specific design • Insulation • Cool Roofs • Solar Zone • Fenestration • Compliance documentation details
NONRESIDENTIAL LIGHTING & ELECTRICAL POWER DISTRIBUTION	• Lighting design strategies • Controls • Electrical power distribution
NONRESIDENTIAL HVAC & PLUMBING	• Mechanical Systems and Plumbing Systems • Commissioning, HERS Process & Acceptance Testing
PROCESS EQUIPMENT & SYSTEMS	• Process loads • Applicable products and systems such as kitchen hoods, parking garage ventilation, laboratory fume hoods, elevators, escalators, and compressors
RESIDENTIAL ENVELOPE & SOLAR-READY AREAS	• Single Family Homes • Duplexes • Climate specific design • Insulation • Cool Roofs • Solar Zone • Fenestration • Compliance documentation details
RESIDENTIAL LIGHTING	• Lighting design strategies • Compliant Products • Controls
RESIDENTIAL HVAC AND PLUMBING	• HVAC terminology • Heating and cooling system types • Hot Water system types

Compliance Process Overview

Chapter 1 begins with an overview of the compliance process including the responsibilities, requirements and documentation involved in each phase of a project, from design to final inspection.

Concepts & Principles

Chapter 2 is devoted to lighting concepts and principles such as color rendering, color temperature, light output, and lamp life. These concepts are vital for making informed decisions about lamps, luminaires and controls.

Technology, Systems and Compliance Strategies

Chapter 3 examines how to create an effective lighting system by pairing the correct source technology with the appropriate luminaire and lighting controls. The guide focuses on lamps, control devices and control strategies.

This section of the guide also describes luminaire classification under the Energy Standards, control strategies, and control systems relevant to commercial spaces.

Compliance Requirements

Mandatory code requirements related to electric lighting, daylighting and lighting controls are explained in Chapter 4. This chapter also examines the prescriptive requirements of the Energy Standards, including the available methods used to calculate allowed lighting power.

Requirements & Recommendations: Prescriptive Approach in Practice

Chapter 5 includes requirements and recommendations for meeting the Energy Standards in specific nonresidential space types. This portion of the guide focuses on how to apply the prescriptive approach to retail, office, and outdoor spaces. Example exercises are included detailing the steps for the prescriptive approach as well as how to complete relevant forms.

NOTE: This guide is not intended to be used in lieu of California's Building Energy Efficiency Standards, and it is not a substitute for the code itself. Please visit **www.energy.ca.gov/title24** to obtain the official 2016 Building Energy Efficiency Standards, Errata, Reference Appendices, and Nonresidential Compliance Manual.

THE COMPLIANCE PROCESS

The following is an overview of the compliance process for nonresidential lighting systems. Additional information and resources, including the 2016 Nonresidential Compliance Manual and forms are found on the California Energy Commission website: ***energy.ca.gov/title24/2016standards.***

Step 1: Discuss and Define Energy-Related Project Goals

Designers, project owners and builders have the best opportunity to identify and pursue energy savings strategies at the beginning of a project. Early coordination with project team members is recommended to clearly define energy related project goals and understand potential opportunities and constraints. When building system commissioning is required, compliance documents indicating project goals called the **Owner's Project Requirements** must be generated.

Step 2: Determine and Design to the Energy Standards

All regulated, nonresidential buildings must be designed and built to comply with the mandatory measures of Title 24, Part 6. Mandatory measures are discussed in Chapter 4. In addition to meeting the mandatory requirements, buildings must also comply with additional requirements specified within the Energy Standards. Both the prescriptive and performance approaches are described in more detail in Chapter 4. Two approaches may be taken to meet these requirements:

The **Performance Approach** provides one path to compliance. It requires using software approved by the Energy Commission to model the energy performance of a building. This method allows for energy trade-offs between building systems and is considered more flexible than the Prescriptive Approach. This approach is often used for the design of new buildings.

The **Prescriptive Approach** does not require building modeling or the same level of building science expertise needed to prepare designs under the Performance Approach. This approach is often utilized for retrofit projects.

Step 3: Prepare and Submit Permit Application

Once a building design has met all applicable requirements in the Energy Standards, the design team must ensure that the plans include all the documents that building officials require to verify compliance. Plans and Certificate of Compliance forms are submitted to the enforcement agency along with the building permit application.

Step 4: Plan Check and Receive Permit

A building department plans examiner must check that the building and systems satisfy Energy Standards requirements and that the plans contain all the necessary information that must be verified during field inspection. A building permit is issued after plans are approved.

Step 5: Pass Inspection and Receive Permit

The installation team must follow the approved plans and specifications during construction. Following installation, the team completes Certificates of Installation to document that all the proper systems were installed in accordance with the building owner's requirements and the Energy Standards. The building department field inspector(s) must verify that the building and installed systems include all items listed on the compliance and installation certificates.

Step 6: Commissioning

Once construction is complete, the contractor or other designated team member must properly commission the building and its systems. They must also advise the building operators of their responsibilities to comply with the Energy Standards. They must provide information or training on how to maintain and operate the building and its energy features. Once the building is commissioned, it is ready for acceptance testing.

Step 7: Test and Verify Compliance

The Energy Standards requires that Certified Lighting Control Acceptance Test Technicians (CLCATTs) review and test certain lighting control systems to ensure controls operate as required by the Energy Standards. CLCATTs must be trained and certified by an approved curriculum provider. Visit energy.ca.gov/title24/attcp for information on CLCATT certification providers.

CLCATTs must:

- Certify that all acceptance testing necessary to meet the requirements of the Energy Standards are completed
- Test installations to ensure controls are positioned and calibrated to operate in compliance with the Energy Standards
- Check that all necessary set points or schedules are in place as required by the Energy Standards and building owner's requirements
- Complete required Certificates of Acceptance and submit these to the enforcement agency

Step 8: Provide Documentation to Building Owners

Upon occupancy, the building owner receives copies of the energy compliance documents, including Certificates of Acceptance, along with instructions for lighting system operation and maintenance.

NEW IN 2016: AN OVERVIEW OF UPDATES

Those familiar with the 2013 Energy Standards will find several changes to the lighting requirements in the 2016 Energy Standards. Below is an overview of the most significant updates.

Reduction to Lighting Power Density Values

Lighting power density allotments have been reduced for many indoor and outdoor spaces including spaces in auditoriums, libraries, and schools. Reductions affect building, area and tailored methods of compliance.

Updated Power Adjustment Factors

The 2016 Energy Standards contain two new power adjustment factors (PAF) that address institutional tuning and daylight harvesting. Three other PAF have been eliminated.

Multilevel Lighting and Occupancy Controls

Multilevel lighting control requirements have been simplified. In addition, spaces that utilize certain types of occupancy controls are no longer required to also include multilevel control. Other occupancy control requirements are now easier to apply in practice.

Alterations

The line between maintenance and retrofit has been redrawn. More projects are now exempt from alteration requirements. Those that are required to comply now have more options including some with reduced control requirements.

COMPLIANCE DOCUMENTS

The compliance process includes the completion of an extensive set of forms, which must be submitted for review by a plans examiner within the authority having jurisdiction. Not all forms are required for all projects. Instructions for completing these forms are provided in Section 6.6 of the Energy Commission's Nonresidential Compliance Manual. Note, lighting controls acceptance test forms must be submitted electronically by the CLCATT.

NR CC – LTI – 01 – E

NR: Nonresidential
CF: Residential

CC: Certificate of Compliance
CA: Certificate of Acceptance
CI: Certificate of Installation
CV: Certificate of Verification

LT: Lighting

CXR: Commissioning Review
ELC: Electrical
ENV: Envelope
MCH: Mechanical
PLB: Plumbing
PRC: Process

O: Outdoor
I: Indoor
S: Signs

Number in Sequence

E: Used by Enforcement Authority
A: Used by Acceptance Tester

Certificates of Compliance

Certificates of Compliance and building plans are submitted at the same time that a building permit application is submitted to the enforcement agency (see Step 4 in the compliance overview). Some Certificates of Compliance are mandatory for every project, while others are required only if the system design includes specific components or strategies.

NRCC-ELC-01-E	Electrical Power Distribution
NRCC-LTI-01-E	Indoor Lighting
NRCC-LTI-02-E	Indoor Lighting Controls
NRCC-LTI-03-E	Indoor Lighting Power Allowance
NRCC-LTI-04-E	Tailored Method
NRCC-LTI-05-E	Line-Voltage Track Lighting Worksheet
NRCC-LTI-06-E	Indoor Lighting Existing Conditions
NRCC-LTO-01-E	Outdoor Lighting
NRCC-LTO-02-E	Outdoor Lighting Controls
NRCC-LTO-03-E	Outdoor Lighting Power Allowance
NRCC-LTO-04-E	Outdoor Lighting Existing Conditions
NRCC-LTS -01-E	Sign Lighting

Because lighting power trade-offs are not allowed between conditioned and unconditioned spaces, most nonresidential indoor lighting compliance documents must be completed separately for conditioned and unconditioned spaces

Certificates of Installation

These forms, signed by licensed professionals, certify that the lighting installed for the project corresponds with the lighting proposed on the Certificates of Compliance. NRCI-LTI-01-E is required for all indoor lighting projects. NRCI-LTO-01-E is required for all outdoor lighting. The other forms may be required based on the specific lighting systems installed.

NRCI-LTI-01-E	Validation of Certificate of Compliance (All Buildings)
NRCI-LTI-02-E	Energy Management Control System or Lighting Control System
NRCI-LTI-03-E	Line-Voltage Track Lighting
NRCI-LTI-04-E	Two Interlocked Lighting Systems
NRCI-LTI-05-E	Power Adjustment Factors
NRCI-LTI-06-E	Video Conferencing Studio Lighting
NRCI-LTO-01-E	Outdoor Lighting
NRCI-LTO-02-E	Energy Management Control System or Lighting Control System
NRCI-LTS-01-E	Sign Lighting
NRCI-ELC-01-E	Electrical Power Distribution

Certificates of Acceptance

A CLCATT, trained and certified through a state-approved program, must complete Certificates of Acceptance when required. The forms are also signed by the responsible person and the document author. These signatories may be different than the CLCATT. Information in these forms certifies that the lighting controls were tested and operate in compliance with the Energy Standards and building owner requirements:

NRCA-LTI-02-A	Lighting Controls
NRCA-LTI-03-A	Automatic Daylighting Controls
NRCA-LTI-04-A	Demand Responsive Lighting Controls
NRCA-LTI-05-A	Institutional Tuning Controls
NRCA-LTO-02-A	Outdoor Lighting Controls

PHOTO: CLTC

FINDING COMPLIANT PRODUCTS

Certain devices must be certified to the Energy Commission as meeting California's Appliance Efficiency Regulations (Title 20, Section 1601 – 1608 of the California Code of Regulations). Others are regulated only under the Energy Standards (Title 24, Part 6).

Products Regulated Under Title 20

The following lighting products are regulated under Title 20. The Energy Standards reference these requirements.

- **Fluorescent lamp ballasts** (**Section 110.9(f)**)
- **Self-contained lighting control devices** (**Section 110.9**)

  - Time-switch lighting controls: automatic time-switch controls, astronomical time-switch controls, multi-level astronomical time-switch controls, outdoor astronomical time-switch controls
  - Daylighting controls: automatic daylight controls, photo controls
  - Dimmers
  - Occupant sensing controls: occupant sensors, motion sensors, vacancy sensors, partial-ON sensors, partial-OFF sensors
- **Ceiling fan light kits**
- **Lamps**
- **Emergency Lighting**
- **Torchieres and Metal Halide Luminaires**
- **Power supplies**

Products Regulated Under the Energy Standards

The following lighting control devices are regulated under **Section 110.9** of the Energy Standards only:

- Part-night outdoor lighting controls (**Section 110.9(b)5**)
- Track lighting integral current limiter
- Supplementary overcurrent protection panels for use with line-voltage track lighting
- Field-assembled lighting control systems

Appliance Efficiency Database

The Energy Commission's Modernized Appliance Efficiency Database (MAEDBS) lists a variety of products certified as meeting the Energy Standards, including lamps, ballasts, and lighting controls. Lighting specifiers wishing to work with a product not yet listed in the Appliance Efficiency Database can encourage the manufacturer or a pre-approved third-party certifier to submit appliance certification data to the Energy Commission.

ENERGY STAR®

While many Energy Star products meet California's efficiency requirements, not all Energy Star labeled products comply with the Energy Standards. In some cases, California's compliance requirements are more stringent. Consult MAEDBS to see if an Energy Star product complies with California requirements.

DesignLights Consortium®

The DesignLights Consortium (DLC) maintains a Qualified Products List that provides information on available products for the commercial sector that passed a review of test results as verification of performance for listed products. Members of the DLC are comprised of regional, state, utility, and energy efficiency programs throughout the United States and Canada. Products on the list are often eligible for incentives through participating programs.

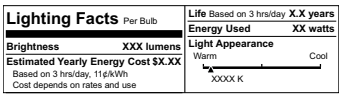
Lighting Facts

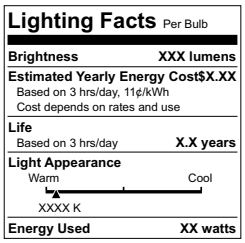
The LED Lighting Facts® is a program of the U.S. Department of Energy that showcases LED products for general illumination from manufacturers who commit to testing products and reporting performance results according to industry standards.

Appliance Efficiency Database

energy.ca.gov/appliances

This online database of products certified to the Energy Commission has a Quick Search function allowing users to search by product type, brand or model name.





Compliant LED Labeling

Above are samples of compliant lighting labeling from the various organizations and government agencies that review products against the guidelines


EXIT

CHAPTER 2

CONCEPTS & PRINCIPLES

LAYERS OF LIGHT

Adding task and accent lighting to spaces lit with general, ambient lighting allows ambient lighting loads to be reduced without compromising safety or visual comfort. In fact, this layered approach to lighting improves visual comfort by reducing contrast. Lighting designs that include task and accent lighting are also more attractive, as they provide variety and visual interest.

Ambient (General) Lighting

Ambient lighting should provide a comfortable level of brightness without causing glare. Most rooms benefit from having an ambient light source in the form of a ceiling-mounted luminaire, recessed lights, wall-mounted luminaires, or a suspended pendants.

Task Lighting

Task lighting supplements ambient lighting and maximizes efficiency by placing light directly on the work area. Users can switch it on only when needed. Compact desktop task lighting, for example, provides extra light for document preparation and review. Undercabinet lighting in the break rooms and commercial kitchens makes cooking and food preparation safer and easier.

Task lighting should be bright enough to prevent eye strain without causing glare. Multiple light sources can cast shadows that make tasks more difficult. High-quality task lighting makes visual tasks easier, and it allows for lower ambient light levels, reducing energy use.

Daylighting

Where daylight is available, electric light levels can often be lowered. In addition to reducing energy use, daylighting is full spectrum lighting that offers excellent color rendering. Controls and window or skylight treatments can be used to prevent glare and unwanted heat from daylight.

Accent or Display Lighting

Track lighting, cove lighting and wall-mounted luminaires are common choices for accent lighting. These luminaires can highlight architectural features, spotlight artwork, or illuminate interior design elements.

Color tunable LED products are becoming more prevalent and more affordable, offering new options for accent lighting. For instance, with the press of a button, retailers can temporarily wash their walls with colored light to accent key product displays.

LUMEN OUTPUT, EFFICACY & LIFE

Many estimate the light output of lamps and luminaires based on the amount of power they draw, but it is lumens (lm), not watts (W), that best describe luminous output. Efficient light sources produce more light while consuming less energy.

Luminous Output

The amount of visible light emitted by a light source is measured in lumens (lm). The more lumens, the more light emitted, but other factors also affect visibility and perception of brightness, such as contrast ratios and color characteristics. In addition, the type of fixture or housing can greatly affect the amount of lighting reaching its intended target.

★ Recommendations

- Compare the light output, not the power rating, of existing and replacement light sources or luminaires to ensure adequate lighting is maintained.
- Consider other factors, such as contrast, distribution and color rendering; these also affect nighttime vision and perceived brightness.
- Install lighting controls, such as dimmers or motion sensors, to maximize energy savings while automatically tailoring light levels to occupants' needs.
- To avoid energy waste and excessive illumination, factor task lighting and ambient lighting into the overall lighting design for a space.

Luminous Efficacy

In lighting, the term efficacy refers to the ratio of luminous output produced by a light source to the power rating of that source (lm/W).

Efficacy = Lumens/Rated Watts

Different source technologies provide different efficacy levels. For example, a 75 W A19 incandescent lamp, a 16 W A19 compact fluorescent lamp (CFL) lamp, and a 15 W A19 LED lamp use different amounts of power to produce the same amount of light (approximately 1,100 lumens). Each type of lamp has a different rated efficacy, with the LED example being the most efficacious (producing the most lumens per watt).

When assessing the overall value of lamps or luminaires, efficacy and longevity should be compared and considered along with initial product cost. Lifetime energy and maintenance costs can often eliminate any cost savings achieved by choosing a lower cost, less efficient product.

Comparing Lumens vs. Watts

LUMENS →	450	800	1,100	1,600
	DIMMER ←			→ BRIGHTER
MORE EFFICIENT ↕ LESS EFFICIENT — Standard Incandescent	40W	60W	75W	100W
Halogen Incandescent	29W	43W	53W	72W
CFLs	10W	13W	16W	20W
LEDs	5W	10W	15W	19W

Sources: U.S. Department of Energy Building Technologies Office, "CALiPER Snapshot: Light Bulbs," October 1, 2013. Natural Resources Defense Council, "Your Guide to More Efficient and Money-Saving Light Bulbs," October 30, 2013.

Life

Electric light sources have the potential to fail due to several factors, including faulty electrical components, corrosion inside the lamp, or lumen depreciation (the gradual decrease in lumen output that occurs over time).

Incandescent lamps typically last 1,000–2,000 hours and lose about 10–15 percent of their initial light output before burning out completely. A CFL lamp lasts about 12,000 hours and loses about 10–15 percent of its output before burning out completely. Linear fluorescent lamps typically last 25,000–40,000 hours, losing 5–10 percent of their original lumen output before they fail

LEDs do not burn out suddenly in the same way as incandescents or fluorescent sources, their lumen output continues to decrease gradually over time. Many LED A19 replacement lamps are rated to last 25,000 hours or more before they lose 30 percent of their initial light output. In addition, testing indicates the diodes (light source) in these products may maintain useful light output longer than these estimates. Follow the following best practices to maximize the life of LED lighting.

★ Recommendations

- Always follow manufacturer installation instructions, including references to base position for replacement lamps (e.g. base-up, base-down or horizontal)
- Pair LED lamps and luminaires with manufacturer recommended dimmers and other controls
- Observe manufacturers' recommendations on operating temperature to prevent heat-related performance degradation

Warranties

Manufacturers offer competitive warranties for lighting products. Energy Star requires that luminaires and LED lamps carry a warranty of at least three years. LED replacement lamps must come with a minimum five-year free replacement warranty in order to meet the Voluntary California Quality LED Lamp Specification and qualify for California utility rebates.

Vision Needs Change with Age

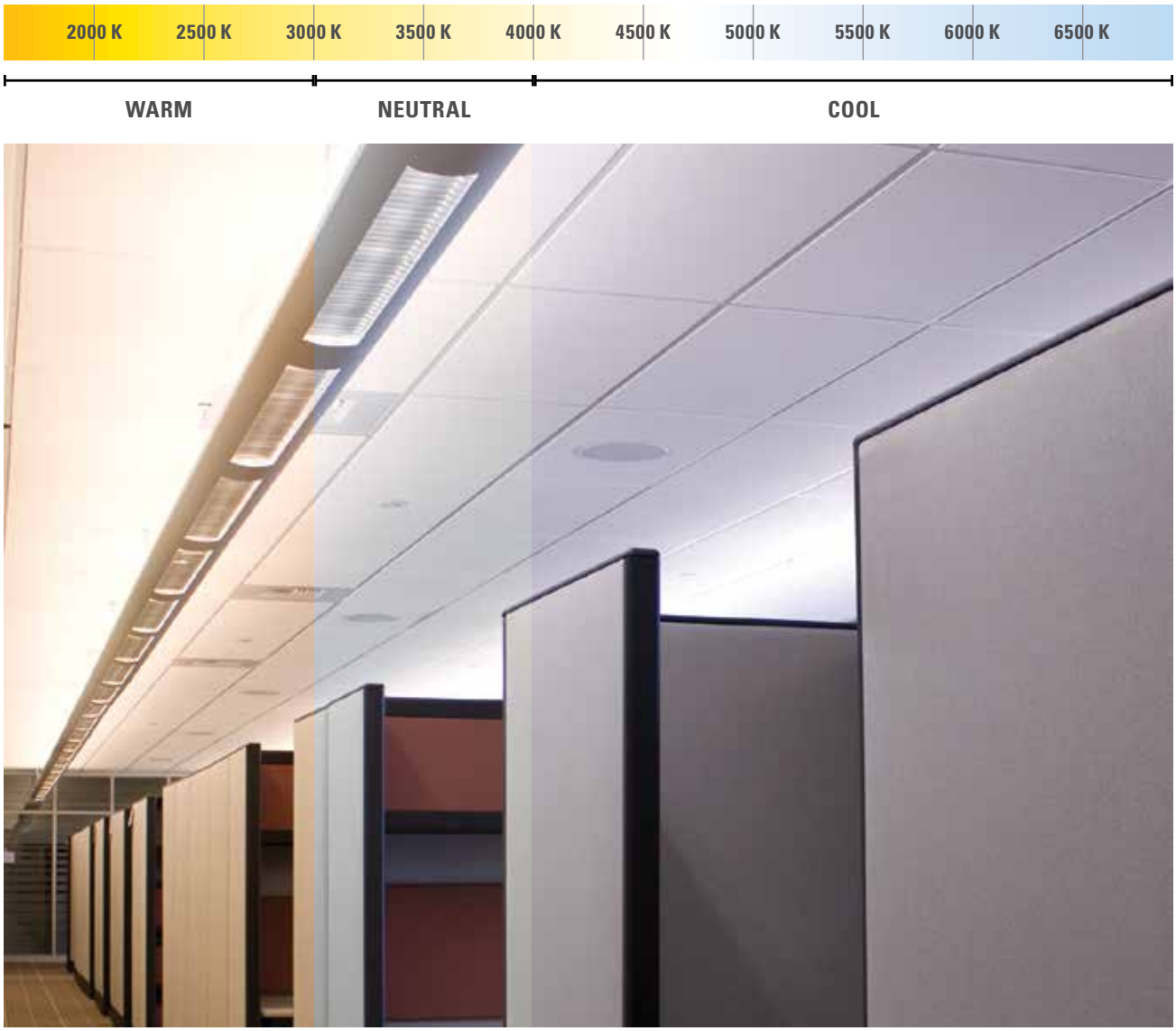
As we age, our eyes require more light to see clearly. The Illuminating Engineering Society of North America (IES) sets lowest average minimum maintained recommendations for light level (lux) requirements based on the needs of occupants under 25 years old. These illumination requirements doubled for those ages 26 – 65 and quadrupled for those over age 65.

COLOR CHARACTERISTICS

Color Temperature

Correlated color temperature (CCT) indicates the warmth or coolness of the light emitted by a given source. CCT is measured on the Kelvin scale (K). Light sources with a low CCT (2,700–3,000 K) give off light that is warm in appearance. Sources with higher CCT values (4,000–6,500 K) provide light with a cooler color appearance.

Selecting light sources with consistent CCTs helps maintain consistency in the appearance of a lighting system that contains multiple luminaires. Check the Lighting Facts label for information on CCT, lumen output, power consumption and luminous efficacy.



Color Rendering

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.

Specifying lamps and luminaires with similar color rendering properties helps ensure wall color, carpeting and other materials have a consistent appearance, especially in adjoining spaces. The full-color Lighting Facts label issued by the Department of Energy includes CRI, but the black-and-white Federal Trade Commission label does not. Most manufacturers can supply information on CRI if it is not immediately available on product packaging or literature.

Comparing Color Quality

The LED MR16 lamps used for these photos both have a CCT of 3000 K and were produced by the same manufacturer. The difference is that the first-generation lamp on the left has a CRI of 80 while the lamp on the right has a CRI of 95.

R9

In the current color rendering metric, fourteen reference colors are used to compare color rendition. The CRI metric measures a light source against the first eight reference colors (R1 – R8). The ninth reference color, R9, is used to measure how a light source's spectral output renders vibrant reds. This measurement is especially critical to consider when illuminating items with saturated red elements, including clothing, jewelry, leather goods, and wood finishes. Cosmetics and customers' skin tones also appear more vibrant when illuminated by sources with an R9 measurement over 50. While the R9 value is not always printed on the lighting facts label, many manufacturers can provide spectrum measurements, including R9 values.

Retrofits with Energy and Fiscal-Related Benefits

California Lighting Technology Center, UC Davis

A lamp-and-ballast retrofit of T8 fluorescent lighting improved lighting quality in the office and reduced lighting energy use 45 percent. 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. These changes saved $1,792 annually.

A case study is available at ***cltc.ucdavis.edu/publication/integrated-office-lighting-system-uc-davis***

CHAPTER 3

TECHNOLOGY, SYSTEMS AND COMPLIANCE STRATEGIES

CHOOSING THE RIGHT LIGHT

An effective lighting system combines the right source technology with the right fixture and the appropriate lighting controls for the desired function and effect. Selecting the right type of light source and lighting controls for different nonresidential lighting needs means comparing a variety of factors, including:

- Luminous output
- Efficacy
- Distribution
- Color rendering
- Controls compatibility
- Correlated color
- Spectral content
- Product life
- Manufacturer warranties
- Long-term energy and cost savings

In many cases, a higher up-front investment in a more efficient, functional lighting system yields a better return in the long term as compared to low-cost alternatives. This is especially true in retail applications, for example, where lighting quality can influence sales. The following technology overview briefly describes the benefits and limitations of commercially available lighting technology and offers guidance for selecting products that comply with the Energy Standards and the Appliance Efficiency Regulations.


PHOTO: CLTC, UC DAVIS


PHOTO: ISTOCK


PHOTO: CLTC, UC DAVIS

OVERVIEW OF LIGHTING PRODUCTS & SYSTEMS

Light Sources

A single luminaire can often accommodate different light sources. For example, screw-based lamps are available with incandescent, CFL or LED sources. Selecting the best source type for a particular application means considering several factors, including light quality, intensity, efficiency, and longevity.

LED

LEDs are solid-state light sources capable of emitting colored light, white light or spectrally-tunable light. The color quality of white light LEDs depends on the materials used in manufacturing the LED chip.

- Installing long-life LED luminaires in areas can reduce maintenance costs and reduce time spent changing failed lamps. LED lighting is excellent for nearly all applications, indoors or outdoors.
- LEDs are dimmable and unaffected by frequent switching. In addition, their compatibility with cold temperatures make them an excellent choice for pairing with occupancy-based controls, such as those used in adaptive freezer case lighting and cold climate outdoor applications.
- Spectrally-tunable LEDs introduce a new element of flexibility and fascination into display and accent lighting. This technology also has potential benefits in healthcare and hospitality applications, where spectral properties of all light sources can impact wake/sleep cycles if the exposure time is significant.

LINEAR LED LAMPS

Replacing existing linear fluorescent lamps with similarly shaped tubular LED lamps requires minimal new hardware, but this strategy also presents challenges that should be understood before purchase or installation.

Based on the particular LED replacement lamp product being considered, this approach typically requires changing the electrical wiring, replacing the ballast with an external driver, or altering the existing lamp holders (or "tombstones") to accommodate the new lamp.

LEDs lamps that replace the fluorescent lamps only and do not require any lighting wiring alterations can be considered a repair and do not trigger the Energy Standards compliance process. The Energy Standards do not regulate tubular LED lamps installed as replacements for linear fluorescent lamps in existing luminaires. However, a project that replaces both fluorescent lamps and ballasts with LED lamps and drivers is a regulated alteration.

Tubular LED Lamp

LED RETROFIT KITS

An LED retrofit kit provides the required electrical components, optical elements and light sources in a prepackaged kit. This replacement option provides an efficient retrofit solution for the majority of troffers in today's building stock. When updating existing troffers, it is critical to make sure they can accommodate the retrofit kit selected since not all retrofit kits are universally accepted by troffers. Any retrofit option should preserve the safety rating of the existing luminaire.

LED Retrofit Kit

DEDICATED LED LUMINAIRES

Dedicated LED luminaires are an excellent alternative to linear fluorescent luminaires. While typically higher in cost than fluorescent products, this option often provides the LED technology in a well-designed package with a straightforward electrical installation.

Dedicated LED Luminaire

For more information, see "LED Retrofit Options for Linear Fluorescent Lighting": ***cltc.ucdavis.edu/publication/led-retrofit-options-linear-fluorescent-lighting***

PHOTO: CLTC, UC DAVIS

LINEAR FLUORESCENT

Linear fluorescent lamps provide uniform levels of illumination for long periods of time, making them ideal in buildings that require bright, uniform ambient lighting. Linear fluorescent lamps also work well in break rooms, bathrooms, storage spaces, and other more utilitarian areas. In addition, these lamps are relatively inexpensive and can provide excellent color rendering.

- Linear fluorescent lamps are available in different wattages and sizes; the four foot long - 32 W T8 is the most common. Low wattage, energy saving alternatives include 28W and 25W lamps. Other products include T5 lamps and lamps in 2' and 8' lengths.
- Not all fluorescent lamps are compatible with dimmable ballasts. Low-wattage lamps are often not recommended for dimming applications. Also, programmed-start ballasts are best suited for frequently switched applications. Ensure fluorescent products selected are suited for the dimming and the multi-level control requirements included in **Section 130.1** of the Energy Standards.

COMPACT FLUORESCENT LAMPS (CFL)

With CFLs, the linear tube design of traditional fluorescent lights has been curved into a more compact shape, facilitating incandescent lamp replacement. An electronic ballast in the base of the CFL activates the lamp then regulates the electrical current. Not all CFLs are dimmable and some can have delayed start times, which can be problematic in some applications.

INCANDESCENT

Incandescent lamps are highly inefficient, however their initial cost is low. These lamps do have excellent color, but they burn out quickly compared to other sources. This can increase maintenance costs over time. In addition, incandescents often provide unwanted heat when used in certain applications. Be selective in choosing applications for incandescent lighting.

HALOGEN

Halogen lamps burn hotter and last longer than standard incandescent lamps, producing a brighter, whiter light. Halogen lamps are also about 25 percent more efficacious than standard incandescent lamps. Halogens are a good alternative when incandescent lighting is necessary.

PHOTO: PHILIPS

METAL HALIDE AND HIGH PRESSURE SODIUM

Metal halide (MH) and high pressure sodium (HPS) lighting is often found in outdoor applications. Both are used in some indoor spaces such as warehouses and other high-bay applications. Metal halide is fairly efficacious and long lived. It can provide CRI of 60 or more. HPS is also very efficacious, but it has poor color properties, producing a yellow light with low CRI. Neither is well-suited for use with occupancy controls or frequent switching. Once extinguished, these technologies take 5 minutes or more before they can be turned back on.

Ceramic metal halide (CMH) lamps are a newer variation of MH technology commonly used in spot and track lighting applications. CMH lamps can produce white light with a CRI as high as 96, making them suitable for color-critical applications. Similar to standard MH lamps, CMH can take up to 10 minutes to reach full light output.

INDUCTION

Induction lamps operate similarly to fluorescent lamps, but without the electrodes and filaments. Induction sources have long lifetimes and seldom need replacing. These lamps are very efficient and compatible with many types of lighting controls and its long life (60,000–100,000 hours) means minimal maintenance. Induction lamps are often used in high bay, low bay and outdoor applications.

Lighting Controls

Lighting controls increase flexibility and functionality of commercial lighting systems. The controls requirements of the Energy Standards aim to maximize lighting system energy efficiency, while also ensuring building occupants are comfortable and safe. There are many control strategies that can be deployed in nonresidential buildings including occupancy control, scheduling, tuning, and automated demand response.

Regardless of the strategy, many lighting controls must be certified to the Energy Commission before they can be used in California buildings. This certification verifies that a device has the minimum functionality required by the Title 20 Appliance Efficiency Regulations and that it meets all state and federal energy efficiency standards.

LED Replacement Options for Linear Fluorescents

Liner fluorescent lamps comprise 80 percent of the lamp inventory in the commercial sector, or about 1.7 billion lamps, according to a U.S. Department of Energy report. LED alternatives to fluorescent lighting products fall into three main categories: tubular lamps, retrofit kits and dedicated luminaires. These LED replacement options have different labor installation times, costs and safety precautions.

LED Retrofit Solution and Advanced Lighting Controls at Watermelon Music

Davis, California

The California Lighting Technology Center conducted an evaluation of LED retrofit solutions paired with advanced lighting control systems in a retail application. The photometric performance of the selected LED linear retrofit kits combined with the advanced lighting control system fulfilled the design goals of meeting IES recommended minimum light levels, providing equivalent or higher light levels than the as-is lighting system, and adhering to the Energy Standards for retail spaces. The following control strategies are deployed at Watermelon Music: scheduling, task tuning, occupancy and daylight harvesting.

Pairing the LED retrofit solution with the fully commissioned advanced control system reduced the annual energy use by 25.2 percent.

A case study is available at: ***cltc.ucdavis.edu/publication/20150609-pge-led-linear-retrofit-solutions-alcs-retail***

CONTROL STRATEGIES

Sensors and controls can achieve significant energy savings by automatically adjusting lighting based on time of day, available task needs, daylight, occupancy, and electricity supply or cost. The controls requirements of the Energy Standards aim to maximize energy savings while ensuring occupants are comfortable.

Tuning

Tuning Controls (left to right): Leviton Renoir II dimming control, Leviton Sapphire LCD Touch Screen

Tuning, also known as high-end trim or institutional dimming, reduces the level of general lighting in an area. Luminaire layouts are designed using a light loss factor, so initial designed light levels are often brighter than necessary. Tuning allows the luminaires to be dimmed to the recommended light level initially and, later, restored to full output when lumen output has degraded. This strategy saves energy, maintains more consistent light levels over the life of the luminaire, and extends lamp life.

What features are required for vacancy sensors?

To be in compliance, a vacancy sensor must provide:

- *A maximum time out of 20-minutes*
- *A 15–30 second grace period to automatically turn lighting ON after the sensor has timed out*
- *No override switch that disables the sensor*
- *A visible status signal that indicates if the device is operating properly (this signal may have an override if the occupant prefers it OFF)*

Occupancy and Vacancy Control

Occupancy Sensors (top row, left to right): Leviton OSSMT Occupancy Sensor, Lighting Control & Design xCella Wireless Occupancy Sensor, Lutron Radio Powr Savr Wireless Occupancy Sensor

Vacancy Sensors (bottom row, left to right): Leviton Provolt Vacancy Sensor, WattStopper CU-250 Ultrasonic Multi-way Wall Switch Vacancy Sensor

What features are required for occupancy sensors?

To be in compliance, an occupancy sensor must provide:

- *A maximum time out of 20-minutes*
- *A visible status signal that indicates if the device is operating properly (this signal may have an override if the occupant prefers it OFF)*
- *Allowance for all lights to be manually turned off regardless of the status of occupancy*

Vacancy sensors automatically dim or switch lighting OFF when the field of view has been vacant for a predetermined, programmed period of time. Occupancy sensors automatically turn lights ON when an occupant is present in the sensor's field of detection. Occupancy sensors can often be programmed to turn only a portion of the controlled lights ON or OFF. This strategy is called Partial-ON or Partial-OFF control. Lights controlled by vacancy sensors, or manual-ON occupant sensors, must be turned on manually. The occupant makes a conscious decision to add electric lighting. This strategy can result in significant energy reductions when general lighting subsequently remains off for the majority of the day.

Daylight Harvesting

Daylight Harvesting Controls (left to right): Leviton ODC05-MDW, WattStopper LMS-600, Lutron Radio Powr Savr Wireless Daylight Sensor

Also called photocontrols, daylight harvesting devices utilize daylight sensors (photocells) to adjust lighting loads based on ambient light levels. Daylight controls are now required in all spaces that have skylights, windows or other daylight sources; at least 120 watts of electric lighting; and 24 square feet of glazing.

Scheduling

Time Clocks (left to right): Leviton EZ-MAX Plus 8 Relay Panel, WattStopper LP8 Peanut Lighting Control Panels

Time switches, commonly used in indoor and outdoor applications, switch lights ON or OFF based on daylight hours and geographical location. Some time clocks and curfew dimming controls can automatically adjust dimmable sources, such as LEDs or CMH lamps, to operate at different levels according to a schedule. Dimming lights during the least active hours of operation reduces energy waste and light pollution.

Automatic Demand Response

Demand Response Controls (left to right): Leviton GreenMax Relay Panel, WattStopper Digital Lighting Management

Utilities initiate demand response events for a variety of reasons. Commercial electricity customers may choose to participate in utility demand response (DR) programs in exchange for financial incentives. Often, these events are issued when demand for electricity is expected to exceed generation capacity. The Energy Standards require all commercial buildings greater than 10,000 ft^2 in size, but excluding spaces with a lighting power density of 0.5 watts per square feet or less, be capable of receiving and automatically responding to DR signals by reducing lighting energy use to a level at least 15 percent below the total installed lighting power, per **Section 130.1(e)**.

Devices vs. Systems

Self-contained lighting control devices are defined in the Energy Standards as "unitary lighting control modules that require no additional components to be fully functional lighting controls." Self-contained devices that are required to be certified to the Energy Commission will be listed in the appliance database.

Networked lighting control systems provide a way to link devices together and have many benefits in building-wide energy management. Systems are not listed in the appliance database and do not need to be certified and listed in MAEDBS. However, the installing contractor must certify compliance via NRCI-LTI-02-E.

Read more in chapter 5.2.2 of the Nonresidential Compliance Manual.

What is the CLCATT looking for?

The CLCATT ensures that the following indoor lighting control devices and systems are installed and functioning properly before the building is occupied:

- *Automatic daylighting controls*
- *Automatic time switch controls*
- *Occupancy sensor*
- *Demand response controls*
- *Institutional tuning controls*

CONTROL ARCHITECTURES

Control systems can be as simple as an ON / OFF switch or as complex as a building-level networked control system that integrates daylight harvesting, occupancy sensing, scheduling, and demand response. There are four control architectures most commonly used in commercial spaces: self-contained lighting control, luminaire-integrated control, circuit-level control and networked control.

Self-Contained Lighting Controls

This is the simplest category of control. This category includes ON / OFF switches, dimmers, photocontrols, and occupancy sensors. Under the Energy Standards, each task area is required to be served by controls that allows occupants to adjust the lighting based on their needs.

Luminaire-Integrated Controls

Also known as on-board controls, these controls come integrated into the luminaire direct from the manufacturer. They can control individual lights locally. Luminaires can come with occupancy and/or daylight harvesting controls.

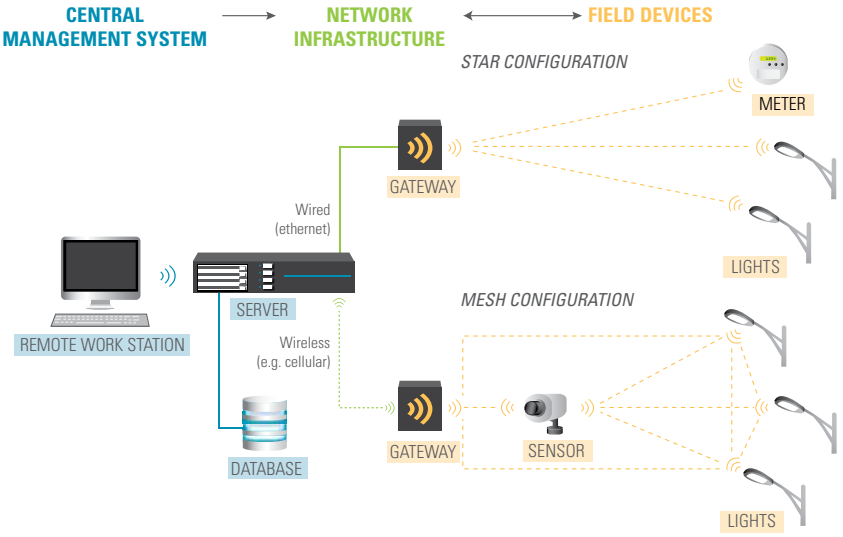
Circuit-Level Control

This control strategy automatically engages entire circuits serving lighting and certain plug loads when those loads are not needed, typically controlling them based on a programmed schedule or area occupancy.

The strategy can be implemented through a timer, or time-clock feature, that enables ON/OFF control based on a schedule defined by hours of building operation. Daylight harvesting and demand response control strategies can also be applied at the circuit level.

Networked Control Systems

Interconnected lighting control systems can control select groups of luminaires or lighting for whole buildings, facilities, or campuses. There are centralized, panel-based wired systems and distributed intelligence systems (available in both wired and wireless forms). The number of lighting control networks and systems on the market has increased in recent years. Interfaces are increasingly user-friendly. These systems can integrate daylight harvesting, advanced scheduling, occupancy-based control demand response, and data monitoring. Lighting can also be controlled as part of a computerized building management system (BMS) or energy management control system (EMCS) that can address HVAC and other systems in addition to lighting. Networked control systems may not override manual controls under the Energy Standards.



Adaptive Corridors at Latham Square
Oakland, California

Energy savings can be achieved in corridors and other secondary spaces with an occupancy-based adaptive lighting system. Such a system is generally composed of occupancy sensors, dimmable ballasts and a communication platform. The system automatically lowers light levels during vacancy and raises light output to the recommended level for occupant comfort during occupied periods. The adaptive lighting system installed at the Latham Square office building is based on Lutron's Energi TriPak solution, a stand-alone platform for adaptive lighting that employs cost-effective wireless control devices and programmable dimming ballasts.

The new 64 W light fixtures installed for this project used dimmable ballasts. Lutron occupancy sensors were installed throughout the corridors to provide adequate passive infrared sensor coverage for the corridor areas and each point of entry. The wireless sensors work in tandem with dimming modules, which control the light level of the fixtures.

A case study is available at: ***cltc.ucdavis.edu/publication/adaptive-corridors-latham-square***


PHOTO: CLTC, UC DAVIS

PHOTO: ACUITY BRANDS

CHAPTER 4

COMPLIANCE REQUIREMENTS

COMPLIANCE OVERVIEW

There are two steps required to comply with the Energy Standards.

1. **Meet all mandatory requirements** by installing required devices, including controls, and ensuring that they perform all required functions.
2. **Select your method** of compliance by choosing either the **Performance Approach** or the **Prescriptive Approach**.

Mandatory Requirements

All nonresidential buildings must meet a set of mandatory requirements for lighting systems and lighting controls. Examples of lighting system components addressed by mandatory measures include switching separation for certain light loads, and use of automatic daylighting controls.

Prescriptive Approach

The Prescriptive Approach is considered the most direct path to compliance. It is a set of prescribed performance levels for various building components, where each component must meet the required minimum efficiency. This approach is often used in retrofit projects.

Performance Approach

The Performance Approach builds on the Prescriptive Approach by allowing energy allotments to be traded between building systems, such as lighting, HVAC or the building envelope. This compliance approach requires using energy analysis software approved by the Energy Commission to model the overall energy performance of a building. The performance approach is often used for new construction projects.

NAVIGATING TITLE 24, PART 6: LIGHTING REQUIREMENTS

	MANDATORY	PRESCRIPTIVE	PERFORMANCE
ADDITIONS, ALTERATIONS AND REPAIRS	—	—	—
Additions	—	§141.0(a)1	§141.0(a)2
Alterations	—	§141.0(b)2	§141.0(b)3 Table 141.0-D
Entire Luminaire Alterations	—	§141.0(b)2.I Table 141.0-E	—
Luminaire Component Modifications	—	§141.0(b)2.J	—
Light Wiring Alterations	—	§141.0(b)2.K	—
Electrical Power Distribution Systems	—	§141.0(b)2.P	—
Outdoor Lighting	—	§141.0(b)L	—
Repairs	§141.0(c)	—	—
GENERAL LIGHTING CONTROLS AND EQUIPMENT	§130.0	§140.6(a)2 and §140.6(d)	—
Manual Area Controls	§130.1(a)	—	—
Multi-level Controls	§130.1(b)	—	—
Automatic Shut-Off Controls: Time Switches and Occupant-Sensing Controls	§130.1(c)	§140.6(a)2.I	—
Automatic Daylighting Controls	§130.1(d)	§140.6(a)2.H and §140.6(d)	—

	MANDATORY	PRESCRIPTIVE	PERFORMANCE
Automated Demand Response	§130.1(e)	§140.6(a)2K	—
Institutional Tuning Controls	—	§140.6(a)2J	—
Lighting Controls Acceptance Tests	§130.4(a), §130.4(c), NA 7.6, NA 7.7.6.1, and NA 7.8	—	—
OUTDOOR LIGHTING CONTROLS	**§130.2**	**§140.7**	—
DAYLIGHTING / GLAZING REQUIREMENTS	**§110.6**	**§140.3**	—
Fenestration: Minimum U-factor, Solar Heat Gain Coefficient (SHGC), Visible Transmittance	§110.6(a)2 Through §110.6(a)6, §110.6(b)	§140.3(a)5	—
Skylights: Maximum skylight to gross roof area, minimum SHGC, Visible Transmittance	—	§140.3(a)6	—
Minimum Daylight Requirements, spaces >5,000 square feet with ceiling heights >15 feet	—	§140.3(c)	—
CONTROL DEVICES AND SYSTEMS, BALLASTS, AND LUMINAIRES	§110.9	—	—
Time-Switch Lighting Controls	§110.9(b)1	—	—
Daylight Controls	§110.9(b)2	—	—
Dimmers	§110.9(b)3	—	—
Occupant-Sensing Controls	§110.9(b)4	—	—
Track Lighting Integral Current Limiter	§110.9(c)	—	—
Track Lighting Supplementary Overcurrent Protection Panel	§110.9(d)	—	—

PHOTO: CREE

MANDATORY REQUIREMENTS FOR INDOOR LIGHTING

Ace Reference™

energycodeace.com/content/reference-ace-2016-tool

The Reference Ace™ tool helps users navigate the Energy Standards documents. Keyword search capabilities along with hyperlinks allow users to jump directly to related sections.

The 2016 version of the Reference Ace links the relevant sections of the Energy Standards, Reference Appendices, Residential and Nonresidential Compliance Manuals, and Residential and Nonresidential ACM Reference Manuals.

BLUEPRINT
California Energy Commission
Efficiency Division

energy.ca.gov/efficiency/blueprint

The Energy Commission's Blueprint Newsletter is published by the Appliances and Outreach & Education Office. Each edition offers information that is helpful in interpreting the Energy Standards in professional practice. Topics are selected based on needs identified by the Energy Standards hotline staff.

Lighting control requirements constitute a large portion of the mandatory lighting requirements contained in the Energy Standards. The requirements for indoor lighting controls are included in **Section 130.1**. For new construction projects, including additions, all subsections within **Section 130.1** must be considered. Certain types of alterations will trigger these requirements as well. However, not all measures must be implemented in every project.

Determining what controls measures will be required in a retrofit project is connected to the quantity of luminaires affected by the project, per enclosed space, and the actual lighting energy use calculations. Some measures may be bypassed if the lighting power density of a space is under certain lighting power density thresholds. LPD requirements are listed under **Section 140.6**.

Under the 2016 Energy Standards, a new, alternate compliance option is available for lighting alteration projects. For projects in hotel, retail, and office buildings, if the total power of the new lighting system is 50 percent or less as compared to the existing system, multilevel lighting controls (**Section 130.1(b)**) are not required. Also, under this compliance path occupancy sensors in library book stacks, corridors and stairwells are not required (**Section 130.1(c)**). For all other types of buildings the savings threshold is just 35 percent below existing.

While most requirement triggers are based on a percentage of affected luminaires or a percentage of an allowed LPD, the demand response controls requirements are triggered by reaching an affected square footage threshold. Alterations that involve 10,000 square feet or less within a single building are not required to comply with **Section 130.1(e)**. To determine which measures affect a project, review **Table 141.0-E**.

All lighting equipment and control devices specified to meet the requirements must be installed according to manufacturer's instructions and lighting controls should follow the performance, acceptance testing, and certification requirements listed in **Section 110.9**.

LIGHTING CONTROLS

Section 130.1–130.2

Mandatory lighting control requirements include provisions for the use of area controls, multilevel lighting, automatic shut-off controls, automatic daylighting controls and demand response control systems. These requirements apply to nearly all new construction projects, both indoors and outdoors. Mandatory indoor requirements can be found in **Section 130.1**. Outdoor requirements are contained in **Section 130.2**. Acceptance test requirements are found in **Section 130.4** and acceptance test procedures in **NA 7.6, 7.7 and 7.8**.

Manual Area Controls

Section 130.1(a)

The luminaires in each area must be independently controlled from luminaires in other areas by manual lighting controls that provide **ON / OFF functionality**.

The Energy Standards call for a manual switch to be located in the same room or area as the lighting it controls. Although lighting control software applications for mobile devices are increasing in availability and lighting may be controllable through these points, it is still necessary to install a switch. Other installed controls may not override manual controls.

SEPARATE CONTROL OF DIFFERENT LIGHTING SYSTEMS

Within each area enclosed by ceiling-height partitions:

- **General lighting** must be controlled separately from all other lighting systems.
- **Ornamental and display lighting**, including lighting for floor and wall displays, window displays, case displays, and special effects lighting, must each be separately controlled on circuits of 20 amps or less.
- When track lighting is used, generally, display, ornamental, and special effects lighting must each be separately controlled. For this reason, it is helpful to designate the purpose of each track (general or display lighting, etc.) on the building plans.

EGRESS LIGHTING

Up to 0.2 watts per square foot of lighting may remain on during occupied hours for emergency egress, but only in building spaces designated for emergency egress on building plans. After hours, only 0.1 watts per square foot is allowed to remain on. Control switches for the egress lighting must not be accessible to unauthorized personnel.

✓ ***EXCEPTION:***

- *Any area less than 100 ft², any larger area with a connected lighting load 0.5 W/ft² or less.*
- *Any area enclosed by ceiling height partitions with only one luminaire and up to two lamps.*
- *Classrooms with general lighting that is 0.7 W / ft² or less and public restrooms need only utilize one control step between 30 and 70 percent of full power.*
- *Areas required to have full or partial-OFF occupancy controls per § 130.1(c)6 and 7.*

Multi-level Lighting

Section 130.1(b)

Dimmable lighting provides the opportunity to reduce lighting energy use while allowing occupants to choose an appropriate light level for each area at any time. The number of mandatory control steps is based on the light source type per **Table 130.1-A**. If multilevel lighting is required, multilevel controls must allow the user to activate all the required control steps. If the lighting is dimmable, the multilevel control must be a dimmer that allows this function plus manual ON and OFF.

For lighting alteration projects where the lighting power density of the area is greater than 85 percent of the allowed lighting power, the lighting alteration project is required to meet all of the multi-level steps described in this section.

Automatic Shut-OFF Controls

Section 130.1(c)

Automatic shut-off controls turn lights off when a space is unoccupied. These controls are required in addition to manual area lighting controls and multilevel control requirements in **Section 130.1(a) and (b)**. For buildings not in continuous operation, almost all lighting should be off when a building is unoccupied. Lighting must be controlled by one or more of the following types of automatic shut-off controls:

- Occupant-sensing controls
- Automatic time switches
- Energy Management Control System

Lighting in each enclosed area and every building floor (except in stairwells) must separately and automatically shut-OFF when the building is vacant. In addition, no more than 5,000 square feet may be covered by a single control. Again, up to 0.1 W/ft² may be left on for building egress. Also emergency lighting that is connected to a separate, emergency power supply and is on only when normal power fails is exempt from shut-OFF requirements.

Countdown timer switches: Countdown timer switches generally do not comply with shut-OFF requirements. However, they are allowed in the following specific applications:

- Single-stall restrooms and closets smaller than 70 square feet
- Server Rooms

In these two areas, the timer switch must be programmed for a maximum time period of 10 minutes for restrooms and closets, and 30 minutes for server rooms.

Automatic Time Switch Control: Where time-switch controls are installed instead of occupant-sensing controls, occupants must have a manual override option that allows the lighting to remain ON outside the scheduled time for a maximum of two hours, as well as automatic holiday shut-off, per **Section 130.1(c)4**.

✓ ***EXCEPTION:***

The maximum size of the control zone increases to 20,000 ft² in:

- *Malls*
- *Auditoriums*
- *Single tenant retail spaces*
- *Industrial facilities*
- *Convention centers and arenas*

The override may exceed 2 hours in the following spaces if captive-key override is utilized:

- *Malls*
- *Auditoriums*
- *Single tenant retail spaces*
- *Industrial spaces*
- *Arenas*

Multi-level Lighting Controls and Uniformity Requirements for General Lighting

Luminaire Type	Minimum Required Control Steps (percent of full rated power[1])	Uniform Level of Illuminance Achieved By:
Line-voltage sockets except GU-24	Continuous dimming 10–100 percent	
Low-voltage incandescent systems		
LED luminaires & LED source systems		
GU-24 rated for LED		
GU-24 sockets rated for fluorescent >20 W	Continuous dimming 20–100%	
Pin-based compact fluorescent >20 W[2]		
GU-24 sockets rated for fluorescent ≤20 W	Minimum one step between 30–70 percent	Stepped dimming; or continuous dimming; or switching alternate lamps in a luminaire.
Pin-based compact fluorescent ≤20 W[2]		
Linear & U-bent fluorescent ≤13 W		
Linear & U-bent fluorescent >13 W	Minimum one step in each range 20–40 percent 50–70 percent 75–85 percent 100 percent	Stepped dimming; or continuous dimming; or switching alternate lamps in each luminaire, having a minimum of four lamps per luminaire, illuminating the same area and in the same manner.
Track Lighting	Minimum one step between 30–70 percent	Stepped dimming; or continuous dimming; or separately switching circuits in a multi-circuit track with a minimum of two circuits.
HID >20 W	Minimum one step between 50–70 percent	Stepped dimming; or continuous dimming; or switching alternate lamps in each luminaire, having a minimum of two lamps per luminaire, illuminating the same area and in the same manner.
Induction >25 W		
Other light sources		

Table 130.1-A in the Energy Standards

[1] Full rated input power of ballast and lamp, corresponding to maximum ballast factor
[2] Includes only pin-based lamps: twin tube, multiple twin tube, and spiral lamps

NOTE: Multi-level controls must not override the functionality of other controls required for compliance.

Occupant Sensing Controls Required: When the following rooms are unoccupied, all the lighting should automatically be turned OFF:

- Offices 250 square feet or less
- Multipurpose room less than 1,000 square feet
- Classrooms of any size
- Conference rooms of any size

The Energy Standards also specify how the lighting in these spaces can be activated by the occupancy sensor. For spaces that also require multilevel lighting controls, sensors must act as a partial-ON device or a vacancy sensor. The partial-ON strategy may only automatically activate between 50 and 70 percent of the controlled lighting. For areas not required to have multilevel controls, the sensor may be a traditional, auto-ON occupancy sensor, a vacancy sensor, or employ a partial-ON strategy.

Full or partial-OFF occupancy controls are required in a variety of additional areas. When a partial-OFF strategy is used, lighting systems must be reduced by at least 50 percent during vacant periods. This is in addition to meeting **Section 130.1(c)1**, which means that there must be an automatic shut-off control to turn lighting off when the space is typically unoccupied.

- Aisle ways and open areas in warehouses
- Library book stack areas
- Corridors
- Stairwells

Parking garages, corridors and stairwells that provide access to hotel guest rooms, and common area corridors and stairwells that provide access to dwelling units in high-rise residential buildings must use a partial-OFF strategy. Guest rooms must use captive card-key controls, occupancy sensing controls, or automatic controls to meet shut-OFF requirements. For hotel and motel guest rooms, the lighting must be shut off no more than 30 minutes after the room is vacated, even if occupancy sensing controls are used.

PHOTO: CLTC

DAYLIGHTING CONTROLS

Section 130.1(d)

The Energy Standards address three types of daylit zones:

1. **Skylit zones:** Areas illuminated by one or more skylights
2. **Primary sidelit zones:** Daylit areas directly adjacent to one or more windows
3. **Secondary sidelit zones:** Areas not directly adjacent to a window but close enough to still receive some daylight

General Lighting in Daylit Zones

Automatic daylighting controls are required for luminaires that meet these criteria:

- Provide general lighting (as opposed to display lighting, decorative chandeliers or ornamental lighting)
- Are located at least partially in a skylit or primary sidelit zone
- Are installed in skylit daylit zones and primary sidelit daylit zones with a total installed general lighting power of 120 watts or more
- Are located in a room with at least 24 square feet of glazing
- Luminaires in skylit and primary sidelit zones must be controlled separately from each other. Luminaires installed where a skylit zone and primary sidelit zone overlap are controlled as part of the skylit zone.

Daylighting Control Requirements

When compliance with this section is required, general lighting will be adjusted when enough daylight is available with automatic daylighting controls that must:

- Provide multi-level lighting in accordance with **Table 130.1-A** unless the lighting power density is less than 0.3 watts per square foot
- Maintain design light levels for each space, i.e., at or above those provided by electric lighting when no daylight is available
- Reduce general lighting power in a daylit zone at least 65 percent when the daylight contribution in that zone is more than 150 percent of the general lighting system's design light level at full power

In projects that qualify as alterations, the daylighting requirements in this section can often be bypassed if the actual lighting power is 85 percent or lower of the lighting power density required for that task area. Also, only altered luminaires need to comply with the daylight control requirements.

PRESCRIPTIVE REQUIREMENTS

When using the prescriptive compliance approach, the requirements for automatic daylighting controls in primary sidelit zones also apply to general-lighting luminaires that are at least 50 percent in, or partially in, a secondary sidelit zone, per **Nonresidential Compliance Manual**.

For rooms, with a roof, located in climate zones 2–15 that are over 5,000 square feet with a ceiling height of greater than 15 feet must have at least 75 percent of their total floor area in daylit zones, per **Section 140.3(c)**.

PHOTO: CREE

Daylight Commissioning

Proper calibration of daylighting controls enables these devices to maintain a proper balance between daylight and electric lighting contributions.

✓ EXCEPTION: Daylighting Control Requirements

Rooms in which the combined total installed general lighting power in the Skylit Daylit Zone and Primary Sidelit Daylit Zone is less than 120 Watts are not required to meet the daylighting control requirements. General lighting in rooms with a total glazing area of less than 24 square feet are not required to meet the daylighting control requirements. Controlled lighting with a lighting power density less than 0.3 W/ft² does not have to meet the multi-level requirements.

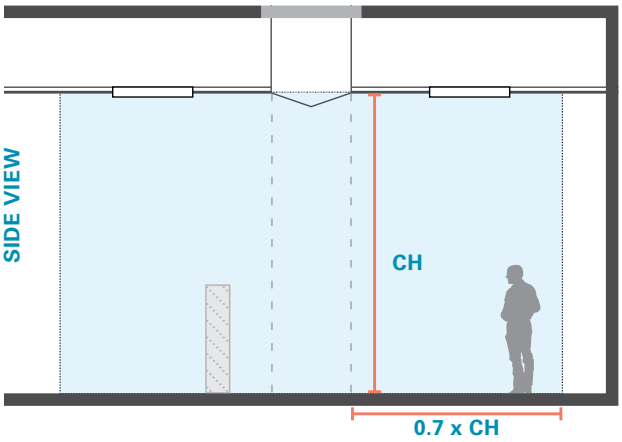
Determining Daylit Zones

All skylit daylit zones and primary sidelit daylit zones must be shown on building plans. Secondary sidelit daylit zones must also be shown on the plans when complying with prescriptive requirements for automatic daylighting controls in secondary sidelit daylit zones. The easiest way to determine the size of daylit zones is examining building plans.

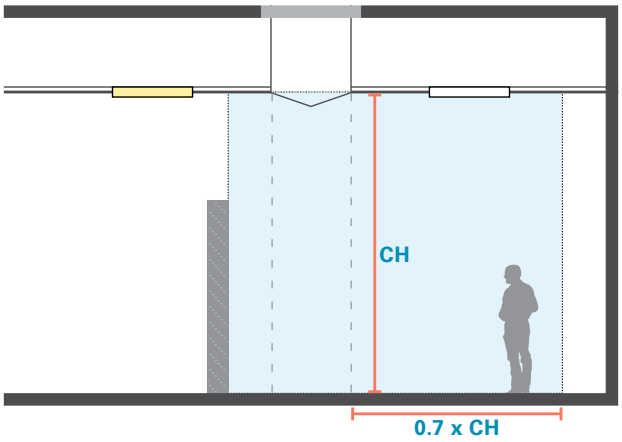
CALCULATING A SKYLIT ZONE

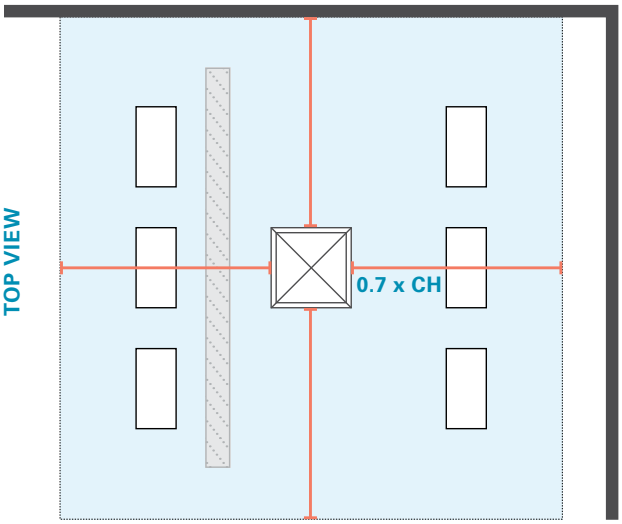
1. **Define the shape of the skylight.** A rectangular skylight produces a rectangular daylight zone, and a circular skylight produces a circular zone, etc.
2. **Determine the average ceiling height (CH) surrounding the skylight.** The ceiling height is the vertical distance from the finished floor level to the ceiling.
3. **Multiply the CH by 0.7**.
4. **Add the value determined in Step 3 in all directions around the skylight** (starting at the edges of the opening).
5. Subtract any area blocked from receiving daylight by a permanent obstruction taller than half the distance from the floor to the bottom of the skylight.

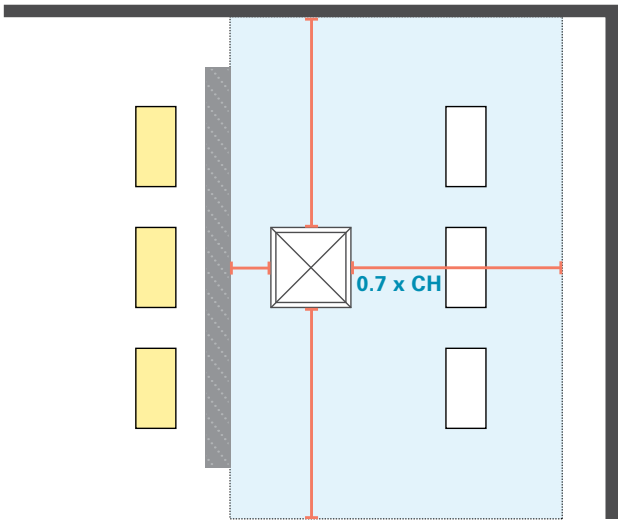
Obstruction height less than half the ceiling height



Obstruction height more than half the ceiling height

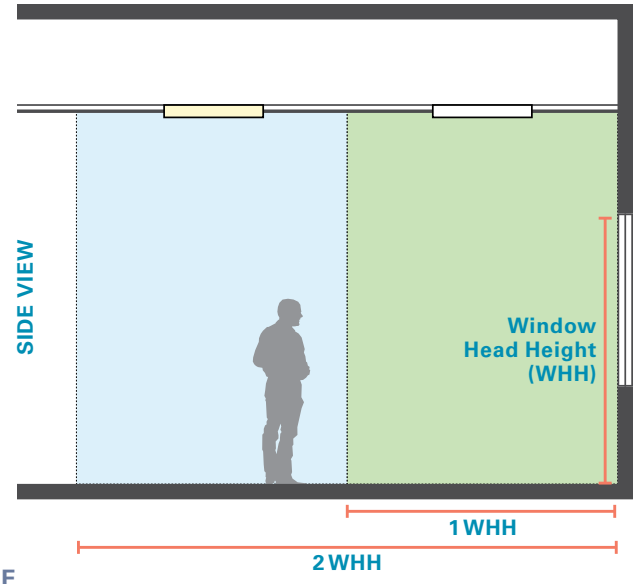






CALCULATING A PRIMARY SIDELIT ZONE

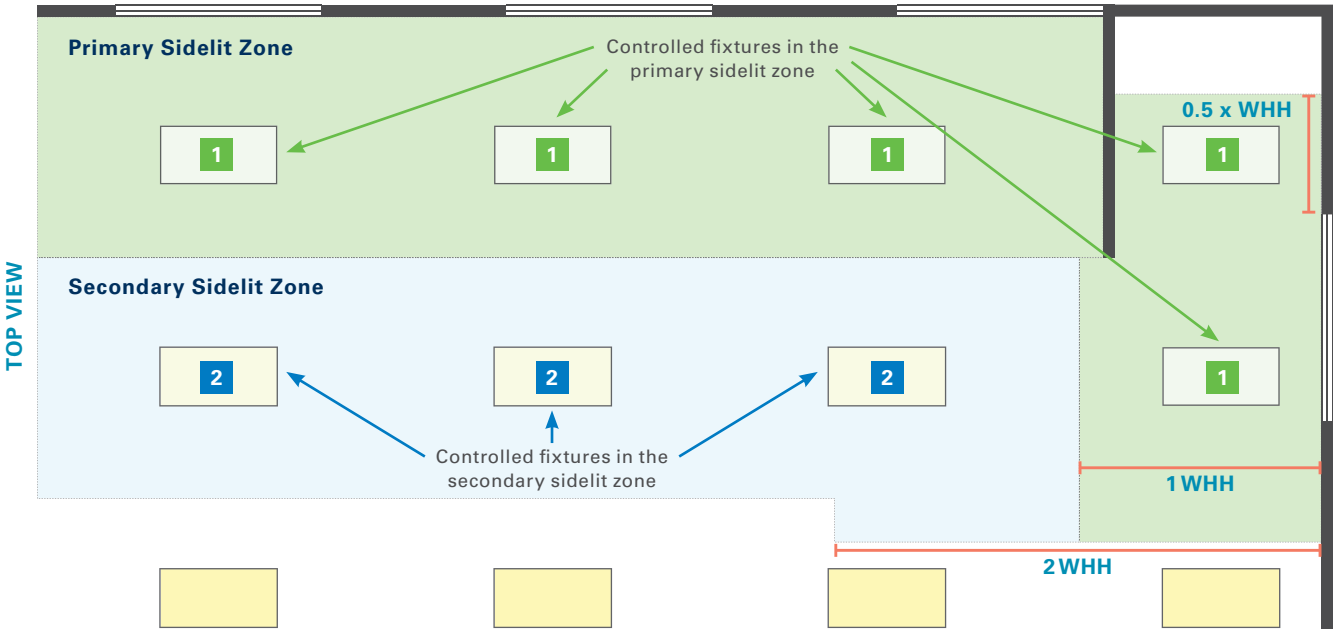
1. **Determine the window head height for each window.** The window head height (WHH) is the vertical distance from the finished floor level to the top of the glazing.
2. **Determine the depth of the zone.** The zone depth is one window head height into the area adjacent to the window.
3. **Calculate the width of the zone.** The zone width is the window's width added to half the window head height on each side of the window.
4. Subtract any area blocked from receiving daylight by a permanent obstruction that is six feet or taller. Modular furniture is not considered a permanent obstruction.



CALCULATING A SECONDARY SIDELIT DAYLIT ZONE

A secondary sidelit daylit zone extends one additional window head height beyond the primary sidelit daylit zone(s) adjacent to it.

1. Add one additional window head height to the same dimensions determined for primary sidelit daylitzones, to determine the depth and width of the secondary sidelit daylit zone.
2. Subtract any area that is blocked from receiving daylight by a permanent obstruction that is 6 feet or taller.



PARKING GARAGES

For parking garage areas with 36 square feet or more of glazing or opening, automatic daylighting controls shall be used to control luminaires that provide general lighting that are in the primary and secondary sidelit daylit zones. They shall meet the following requirements:

1. All primary and secondary sidelit daylit zones shall be shown on the plans.
2. Automatic Daylighting Control Installation and Operation. Automatic daylighting control shall be installed and configured to operate according to all of the following requirements:
   - Automatic daylighting controls shall have photosensors that are located so that they are not readily accessible to unauthorized personnel. The location where calibration adjustments are made to the automatic daylighting controls shall be readily accessible to authorized personnel but may be inside a locked case or under a cover which requires a tool for access.
   - Automatic daylighting controls shall be multilevel, continuous dimming or ON/OFF.
   - The combined illuminance from the controlled lighting and daylight shall not be less than the illuminance from controlled lighting when no daylight is available.
   - When illuminance levels measured at the farthest edge of the secondary sidelit zone away from the glazing or opening are greater than 150 percent of the illuminance provided by the controlled lighting when no daylight is available, the controlled lighting power consumption shall be zero.

✓ ***EXCEPTION: Section 130.1(d)3***

- *Luminaires located in the daylight transition zone and luminaires for only dedicated ramps. Daylight transition zone and dedicated ramps are defined in Section 100.1.*
- *The total combined general lighting power in the primary sidelit daylight zones is less than 60 watts.*

Demand Response Controls

Section 130.1(e)

Automated demand response (ADR) programs use energy management technologies and controls to reduce peak demand and stabilize the grid more quickly and reliably than manual demand response (DR). An automated DR signal is sent from a utility, independent system operator or other power provider to energy management control systems enrolled in ADR programs. The automated systems then reduce electricity use temporarily, according to pre-programmed load shed strategies. Buildings that have more than 10,000 square feet of space with a lighting power density greater than 0.5 W/ft^2 must include demand responsive controls that allow lighting power to be reduced automatically in response to a demand response signal. The total lighting power must be reduced by at least 15 percent of full power. While the DR controls are required by the Energy Standards, participation in utility DR programs is not. Building owners have the option to enroll in DR programs.


PHOTO: CREE

MANDATORY REQUIREMENTS FOR OUTDOOR LIGHTING

Section 130.2

The Energy Standards requirements for outdoor lighting apply to hardscape areas. This typically consists of the paved portions of an outdoor building site but may also include planters or other small areas of landscaping within the application area. **Sections 110.9, 130.0, 130.2, 130.4**, and **140.7** apply to newly constructed outdoor lighting systems. **Section 141.0** applies to outdoor lighting systems that are either additions or alterations.

The following outdoor lighting applications are regulated under the Energy Standards:

Application	Code Section
Hardscape areas: Parking lots, private roadways, driveways, sidewalks, walkways, bikeways, and piazas	130.2 Outdoor lighting controls and equipment 140.7 Requirements for outdoor lighting
Signage	130.3(a)2 Outdoor sign lighting controls 130.3(c)3 Demand response for electronic message centers 140.8(a) Maximum allowed lighting power OR 140.8(b) Alternate lighting sources

LIGHTING ZONES

Section 10-114

Dark-Sky Ordinances

A growing number of local governments have passed dark-sky ordinances that lower lighting power allowances as compared to the Energy Standards. Check with the local permitting authority to determine if the project site's default lighting zone designation has been altered by local jurisdiction.

The Energy Commission must review and approve any changes to LZ designation.

Beginning with the 2005 Energy Standards, the California Energy Commission has specified lighting power allowances based on project locations and whether the surrounding environment is wild (dark), rural (characterized by low ambient light levels) or urban (characterized by higher ambient light levels).

Lighting Zones

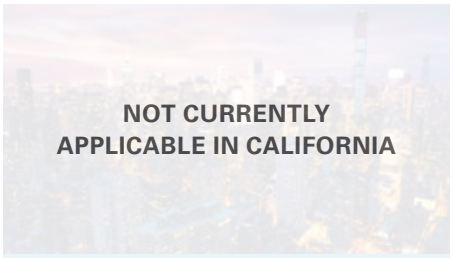
Requirements for Lighting Zone 0 have been added to the Energy Standards. Lighting Zone 0 is designated specifically for undeveloped areas in parks and preserves, where no continuous lighting is intended. While continuous lighting in Zone 0 is now explicitly prohibited, sites may utilize a single luminaire of 15 W or less at entrances to parking lots, trail heads, or other areas in order to safely illuminate site facilities.

Lighting Zone 0 (LZ0)
Dark: undeveloped open spaces

Lighting Zone 1 (LZ1)
Low: parks and preserves

Lighting Zone 2 (LZ2)
Moderate: rural areas

Lighting Zone 3 (LZ3)
Moderately High: urban areas



Lighting Zone 4 (LZ4)
High

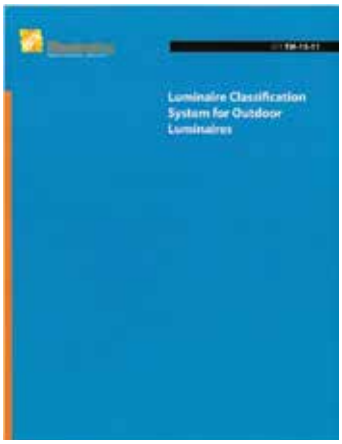
NOTE: *LZ4 is not a default designation. LZ4 designation can only be granted by the Energy Commission when a local government applies for exceptionally high lighting power allowances.*

In addition, luminaires installed in Lighting Zone 0 cannot exceed the maximum zonal lumen limits for Uplight and Glare specified in **Table 130.2-A** and **130.2-B** of the Energy Standards.

Lighting Zone 1 (LZ1) maintains the lowest illumination level with the lowest lighting power allowances; this is the default designation for developed areas in government parks, recreation areas and wildlife preserves. LZ2 is the state default designation for rural areas, and LZ3 is the state default designation for urban areas. There are no Lighting Zone 4 (LZ4) areas in California, but LZ4 allows the highest lighting power allowances.

Lighting zones are based on the latest (2010) U.S. Census Bureau data. They are designed to help limit light pollution and ensure light levels are appropriate for the purposes different areas serve.

To determine the lighting zone for a project, visit the U.S. Census Bureau's FactFinder website, **factfinder2.census.gov**, select Advanced Search, Geographies, and the Address tab. Then enter the site address to determine if the site is in an urban area. If this is not indicated, the site is designated as rural.



IES BUG Rating Resources

ies.org

More on how BUG ratings are calculated, along with tables and examples, can be found in IES Technical Memorandum TM-15-11, "Luminaire Classification System for Outdoor Luminaires."

A list of BUG ratings and tables can also be found at: ***iesna.org/PDF/Erratas/TM-15-11BUGRatingsAddendum.pdf.***

BACKLIGHT, UPLIGHT & GLARE (BUG) RATING SYSTEM

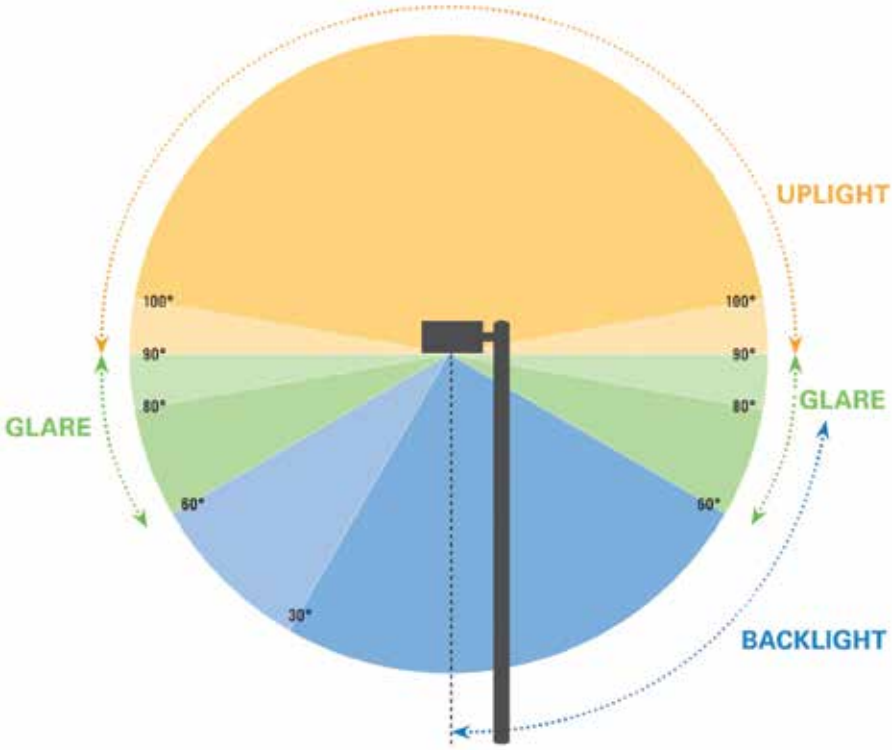
Section 130.2(b)

Conscientious lighting designers have long sought to minimize adverse effects of nighttime lighting with luminaires that limit backlight (or light trespass), uplight (sky glow or light pollution) and glare (high-angle brightness). In 2005, the Illuminating Engineering Society (IES) began implementing the TM-15-07 / BUG system in place of its older cutoff system of luminaire classification.

The BUG rating system helps lighting designers and engineers select luminaires that meet state and local requirements for different outdoor lighting zones (LZ0 – LZ4). The BUG system also allows for better comparison of solid-state luminaires with traditional HID luminaires. The 2016 Energy Standards include requirements limiting uplight and glare in certain applications. These requirements are based on best practices for lighting different applications while minimizing light pollution and energy waste.

A BUG rating consists of three parts, which indicate how well the luminaire controls backlight, uplight and glare. Lower ratings indicate minimal amounts of stray light, light pollution or glare. The lowest possible rating in each category is 0 (B0, U0 or G0). Higher ratings, the highest being 5 (B5, U5 or G5), indicate poorer control. For example, a luminaire rated B2-U0-G1 delivers mediocre control of backlight, offers excellent control of uplight, and controls glare well.

BUG ratings correspond with the amount of light emitted at each secondary solid angle within the backlight, uplight or glare angles. Tables 130.2-A and 130.2-B of the Energy Standards list the zonal lumen maximums allowed for uplight and glare within each outdoor lighting zone. The BUG ratings for different luminaires are included in most manufacturers' photometric reports.



Uplight is defined as excess lighting directed up into the night sky, above 90 degrees. This causes light pollution, or artificial sky glow.

Glare is caused by light emitted between 60 and 90 degrees around a luminaire. Light emitted at these angles can be uncomfortable and even hazardous.

Backlight includes all illumination behind a luminaire. Backlight causes light trespass, which occurs when light spills into unwanted areas.

Compliance Requirements

Applications with Uplight and Glare Limits: Outdoor luminaires using lamps or light sources rated greater than 150 watts must comply with uplight and glare limitations if installed in the following areas:

1. Parking lots and service stations
2. Building entrances
3. All canopies
4. Outdoor dining areas
5. All outdoor sales areas

Applications without BUG Limits: Lamps and luminaires in these applications are not required to comply with BUG requirements:

1. Signs
2. Building facades, public monuments, statues, and vertical surfaces of bridges
3. Lighting required for health or safety
4. Temporary lighting
5. Replacement pole-mounted luminaires in areas where all of the following are true:
   - Connected lighting power is not increased
   - No new wiring is being installed
   - No additional poles are being added
   - Spacing between poles is greater than six times the mounting height of the existing luminaires
   - Existing luminaire does not meet the luminaire uplight and glare zonal lumen limits

The Energy Standards do not require luminaires selected for these purposes to comply with BUG limits, but best practices dictate limiting light trespass and preserving dark skies whenever possible.

REQUIRED CONTROLS

All Outdoor Lighting

Section 130.2(c)1

All outdoor lighting must be equipped with photocontrol OR an astronomical time switch device that turns OFF all lighting when sufficient daylight is available

Section 130.2(c)2

All outdoor lighting must:

- **be controlled independently** from other electrical loads. You must use an automatic scheduling control.
- **use an** automatic scheduling control.

Why 24 Feet?

Testing determined that 24 feet is the current maximum height at which passive infrared sensors, the most commonly available sensor technology, can maintain reliable detection levels around the connected luminaire. Luminaire mounting height is measured from the bottom of the luminous opening.

Incandescent-compatible Luminaires

Section 130.2(a)

A **motion sensor** is required for any outdoor luminaire capable of operating an incandescent lamp greater than 100 watts, even if it is not currently using an incandescent lamp.

Luminaires Mounted Up to 24 feet

Section 130.2(c)3

When mounted so the bottom of the luminaire is 24 feet above the ground or lower, luminaires must be controlled as follows:

1. **Automatic 40 – 90 percent dimming required during vacant periods** When an area is unoccupied, controls should automatically reduce the lighting power of each luminaire at least 40 percent but no more than 90 percent or provide continuous dimming through a range that includes 40 – 90 percent. When the area becomes occupied, controls should automatically increase light levels.
2. **No more than 1,500 watts** of lighting power may be controlled together in a single zone.

EXCEPTIONS

1. **Pole-mounted luminaires** with a maximum rated wattage of 75W.
2. **Non-pole mounted luminaires** with a maximum rated wattage of 30W.
3. **Linear lighting** with a maximum wattage of 4W per linear foot of luminaire.
4. **Sales frontage** that uses a part-night control device instead of a motion sensor.
5. **Lighting for building facades (except for wall packs), ornamental hardscape and outdoor dining areas** that use a part-night control or centralized time-based lighting control instead of a motion sensor.
6. **Applications also listed** as exceptions to **Section 140.l7(a).**

Wall Packs

Where the bottom of a wall pack is mounted 24 feet above the ground or lower, the luminaire must be controlled by a motion sensor that automatically reduces lighting power 40–90 percent during vacant periods.

Part-night Control Requirements

Section 110.9(b)5

A part-night lighting control is a time-based or occupancy-based device programmed to reduce or turn OFF power to an outdoor luminaire for a portion of the night.

To be in compliance, part-night controls must:

1. Predict sunrise and sunset within 15 minutes.
2. Keep time accurately within five minutes.
3. Be able to set back or turn OFF lighting at night via a time-clock or motion sensing device.
4. Time-clock controlled devices must be fully programmable by users, so lighting can be set back or turned OFF from any time at night until any time in the morning.

Adaptive Exterior Lighting at VacaValley Hospital

Vacaville, California

Prior to installing the networked LED system, NorthBay VacaValley Hospital's exterior lighting consisted of 40 induction luminaires, 13 high-pressure sodium (HPS) luminaires, and 7 metal halide luminaires, all operating at full lighting power throughout the night. A total of 57 luminaires were installed with dimmable LED technology for the lighting demonstration. Motion sensors were installed to provide maximum coverage of the site, ensuring lights operate at sufficient levels when occupants are detected and use less energy when areas are vacant. An "ultra-smart" lighting control network was also put in place, giving facility managers the ability to adjust lighting schedules, light levels and time-out settings, monitor the system's energy use, and receive automated alerts when luminaires require maintenance.

UC Davis's California Lighting Technology Center (CLTC) customized the lighting components to integrate them into a single, fully functional system and worked with hospital personnel to ensure system settings meet the site's lighting needs. The retrofit reduced the site's exterior lighting energy use by 66.4 percent, dramatically reduced lighting maintenance needs, and received positive reviews from about 88 percent of end-users surveyed for feedback.

A case study is available at: ***cltc.ucdavis.edu/publication/networked-adaptive-exterior-lighting-health-care-sector***

PHOTO: CLTC, UC DAVIS

LIGHTING CONTROLS ACCEPTANCE TESTING

Section 130.4

Lighting control systems must be tested after they are installed and commissioned. Acceptance tests are required under the Energy Standards and tests must be conducted by a certified lighting controls acceptance test technician. Both indoor and outdoor lighting control systems must be tested. Tests ensure that controls operate in accordance with the Energy Standards and the building owners requirements. Functional test results must also be included in commissioning documents when required under **Section 120.8.**

Acceptance testing is required for the following lighting control systems:

- Automatic Daylighting controls
- Shut-OFF controls
- Demand Response controls
- Outdoor lighting controls
- Institutional Tuning Controls when used to receive a power adjustment factor (PAF)

CALCTP-AT Technician Training

calctp.org

CALCTP is one of two training and certification programs recognized and approved by the Energy Commission to carry out lighting controls acceptance testing as required by the Energy Standards.

In order to be certified as a CALCTP Acceptance Test Technician, a person must:

- *Be employed by a listed CALCTP-certified employer:* ***calctp.org/acceptance-technicians/contractors***
- *Have at least three years of experience with lighting controls*
- *Register on the CALCTP website:* ***calctp.org/acceptance-technicians***
- *Take the training course offered at one of the CALCTP training centers:* ***calctp.org/training-center-list***

ELECTRICAL POWER DISTRIBUTION SYSTEMS

Section 130.5

The Energy Standards regulate certain aspects of electrical power distribution systems. These requirements are intended to improve building energy efficiency by providing the electrical infrastructure necessary to enable energy - use metering and plug-load shut-OFF controls. When building owners and operators can understand the energy use of specific building systems and appliances, they can more easily make decisions regarding efficiency programs and upgrades. With the advent of smart meters, energy data is now readily available. By ensuring that individual loads are capable of being separately monitored and controlled, building energy efficiency can be greatly improved. These mandatory requirements apply to new construction, additions, and alterations.

Service Metering

Table 130.5-A

A building's electrical service must have an electrical metering system to measure instantaneous demand and energy consumption over a user defined period.

The electrical service meter must:

- Display instantaneous demand in kW.
- Measure kWh usage over time.
- Larger services rated greater an 250 kVA require additional capabilities.

Utility-provided "Smart meters" usually meet the requirements as long as they can measure instantaneous demand and energy consumption over a utility-defined period.

Disaggregation of Electrical Loads

Requirements for disaggregation of electrical load types change depending on the rating of the building's electrical service. The separation of electrical loads, when required, is intended to allow for measurement devices to be able to monitor electrical energy usage for different load types, according to **Table 130.5-B**.

For services greater than 50 kVA, additional load types must be disaggregated, so most projects less than 5,000 square feet will not be required to comply. Buildings with an electrical service rated greater than 50 kVA are required to separate additional load types, per **Table 130.5-B**. Buildings must be wired to be capable of monitoring load types separately. This requirement does not require any metering. By placing all loads of a particular type on one feeder, a portable device can be temporarily attached to that feeder to allow for measurements. This is mandatory, and will likely affect new buildings and for major additions or renovations. If the existing service switchboard, feeders, and panel boards remain unchanged, this requirement is not triggered.

Voltage Drop

The maximum combined voltage drop on both installed feeder conductors and branch circuit conductors to the farthest connected load or outlet cannot exceed five percent. Exceptions to **Section 130.5(c)** are voltage drops permitted by **Sections 647.4, 695.6, and 695.7** of the California Electrical Code.

Circuit Controls for 120-V Receptacles

In all buildings, both controlled and uncontrolled 120 volt receptacles must be provided in office areas, lobbies, conference rooms, kitchen areas in office spaces, and copy rooms.

Controlled receptacles must meet all the following requirements, as applicable:

1. Install a control capable of automatically shutting OFF the controlled receptacles when the space is typically unoccupied, either at the receptacle or circuit level. When an automatic time switch control is installed, it must use an override control that allows the controlled receptacle to remain ON for no more than 2 hours when an override is initiated and an automatic holiday "shut-OFF" feature that turns OFF all loads for least 24 hours and then resumes the normally scheduled operation. Countdown timer switches cannot be used to comply with the automatic time switch control requirements.
2. Install at least one controlled receptacle within 6 feet from each uncontrolled receptacle, or install a split-wired receptacle with at least one controlled and one uncontrolled receptacle. Where receptacles are installed in modular furniture in open office areas, at least one controlled receptacle shall be installed at each workstation.
3. Provide a permanent and durable marking for controlled receptacles or circuits to differentiate them from uncontrolled receptacles or circuits.

For hotel and motel guest rooms, install controlled receptacles for at least one-half of the 120-volt receptacles in each guestroom. Electric circuits serving controlled receptacles in guestrooms shall have captive card key controls, occupancy sensing controls, or automatic controls so the power is switched off no longer than 30 minutes after the guestroom has been vacated.

A hardwired power strip controlled by an occupant sensing control may be used to comply with these requirements, however, plug-in strips and other plug-in devices cannot.

EXCEPTION: Section 130.5(d)

Receptacles used for the following purposes are exempt from **Section 130.5(d)** requirements:

i. Receptacles specifically for refrigerators and water dispensers in kitchen areas.

ii. Receptacles located a minimum of six feet above the floor that are specifically for clocks.

iii. Receptacles for network copiers, fax machines, A/V and data equipment other than personal computers in copy rooms.

iv. Receptacles on circuits rated more than 20 amperes.

v. Receptacles connected to an uninterruptible power supply (UPS) that are intended to be in continuous use, 24 hours per day/365 days per year, and are marked to differentiate them from other uncontrolled receptacles or circuits.

Demand Responsive Controls and Equipment

Demand responsive controls and equipment, where installed, must be capable of receiving and automatically responding to at least one standards-based messaging protocol which enables demand response after receiving a demand response signal.

PERFORMANCE APPROACH

The Performance Approach to compliance is a software-based method that uses energy modeling to plan for an energy efficient building. This method is commonly used in new construction projects, rather than lighting retrofits.

Approved Computer Compliance Programs

energy.ca.gov/title24/2016standards/2016_computer_prog_list.html

More information on "Approved Computer Compliance Programs" is available through the Energy Commission's website.

System Trade-offs Allowed

In addition to meeting mandatory requirements, actual lighting power may not exceed LPD limits set forth by the Energy Standards, unless traded with other energy features of the building using the Performance Approach. The Performance Approach to compliance is recommended for professionals with experience using software modeling to manage energy budgets.

Under the Performance Approach, trade-offs may be made between different systems within a building. For example, use of energy-efficient lighting can allow more installed power for heating and cooling. There is no trade-off benefit to using this method on projects that only affect the lighting system.

Approved Software Required

Those choosing the Performance Approach must use software to model building energy use, and that software must be approved by the Energy Commission. At the time this guide was created, two programs were approved for use with nonresidential building projects:

- **CBECC-Com 2016.2.1:** CBECC-Com uses EnergyPlus v8.5 to perform simulations and Sketchup (v8.0/Pro) with OpenStudio SketchUp Plugin for geometry input. Software can be downloaded at: **bees.archenergy.com/software2016.html**
- **EnergyPro Version 7.1 Nonresidential:** This software was approved for demonstrating compliance with the nonresidential provisions of the 2016 Energy Standards. Software can be downloaded at: **energysoft.com/download/energypro-7**


PHOTO: FINELITE

PRESCRIPTIVE APPROACH

When choosing the Prescriptive Approach to lighting power density compliance, choose one of the following methods to calculate the allowed indoor lighting power for each room or area of a building:

1. **Complete Building**
2. **Area Category Method**
3. **Tailored Method**

All three methods involve multiplying the area of a space (square feet) by the allowed LPD (W/ft^2) for that space and adding special allowances for display lighting and decorative or ornamental lighting. Actual lighting power may not exceed this allotment.

With the Prescriptive Approach, trade-offs are limited to general lighting power and restricted to certain space types. Under the Prescriptive Approach, the actual lighting power is compared to an allowed lighting power total. If the actual is less than or equal to the allowed, the project complies with the lighting power budget requirements.

The Complete Building Method is used when all areas of the building are of the same space type. The Area Category Method is used for buildings with multiple space types and can be used in combination with the Tailored Method. The third method, the Tailored Method is an option for areas that utilize lighting to highlight unique features. The Tailored Method may be used for, retail spaces, a lobby or a waiting area where awards or artwork is displayed.

Prescriptive Approach in Practice

At the end of this section are exercises for lighting power adjustments, Complete Building Method, and Area Category Method.


PHOTO: CREE

Lighting Power Allowance

The Energy Standards regulate lighting power by space or building type. The lighting power allowances are typically reduced with each iteration of the Energy Standards. Regulations affect projects using any of the three compliance methods: area category, complete building or tailored. Buildings such as auditoriums, libraries, schools, restaurants and medical buildings saw the largest reductions in allowed lighting power under the 2016 Energy Standards. For those using the tailored method to determine allowed lighting power, significant changes affect all space types.

Power Adjustment Factors

During design, projects may receive credits to the total installed power by installing certain types of lighting controls. These Power Adjustment Factors (PAF) reflect control strategies that exceed requirements contained in the Energy Standards. PAF are available for:

- Demand Response Controls installed in buildings 10,000 square feet or smaller
- Institutional Tuning controls
- Occupant Sensing Controls in Large Open Plan Offices
- Daylight Dimming plus OFF Control

Complete information on lighting power allowances and power adjustment factors for indoor spaces can be found in **Section 140.6**. Outdoor requirements are contained in **Section 140.7**.

Lighting Power Adjustment Factors (PAF)

Type of Control	Type of Area		Factor
a. To qualify for any of the Power Adjustment Factors in this table, the installation will comply with the applicable requirements in **Section 140.6(a)2** b. Only one PAF may be used for each qualifying luminaire unless combined below c. Lighting controls that are required for compliance with the Energy Standards shall not be eligible for a PAF			
Daylight Dimming plus OFF Control	Luminaires in skylit daylit zone or primary sidelit daylit zone		0.10
Occupant Sensing Controls in Large Open Plan Offices	In open plan offices >250 ft²: One sensor controlling an area that is:	No larger than 125 ft²	0.40
		From 126 to 250 ft²	0.30
		From 251 to 500 ft²	0.20
Institutional Tuning	Luminaires in non-daylit areas: Luminaires that qualify for other PAFs in this table may also qualify for this tuning PAF.		0.10
	Luminaires in daylit areas: Luminaires that qualify for other PAFs in this table may also qualify for this tuning PAF.		0.05
Demand Responsive Control	All building types less than 10,000 sq. ft. Luminaires that qualify for other PAFs in this table may also qualify for this demand responsive control PAF		0.05

Table 140.6-A in the Energy Standards

Lighting Power Density Updates 2013 to 2016: Area Category Method

Primary Function Area		Allowed Lighting Power Density (W/ft²) 2016	Δ
Auditorium Area		1.4[3]	0.1
Convention, Conference, Multipurpose and Meeting Center Areas		1.2[3]	0.2
Dining Area		1.0[3]	0.1
Electrical, Mechanical, Telephone Rooms		0.55[2]	0.15
Exhibit, Museum Areas		1.8	0.2
Financial Transaction Area		1.0[3]	0.1
Hotel Function Area		1.4[3]	0.15
Kitchen, Food Preparation Areas		1.2	0.2
Laundry Area		0.70	0.2
Library Area, Reading Areas		1.1[3]	0.1
Lobby Area	Hotel lobby	0.95[3]	0.15
	Main entry lobby	0.95[3]	0.55
Locker / Dressing Room		0.70	0.1
Lounge Area		0.90[3]	0.25
Malls and Atria		0.95[3]	–
Transportation Function Area	Concourse & Baggage	0.50	–
	Ticketing	1.0	0.3
Waiting Area		0.80[3]	0.1
All other areas		0.50	0.1

*Footnotes for **Table 140.6–C**: See **Section 140.6(c)2** for an explanation of additional lighting power available for specialized task work, ornamental, precision, accent, display, decorative, and white boards and chalk boards, in accordance with the footnotes in this table. The smallest of the added lighting power listed in each footnote below, or the actual design wattage, may be added to the allowed lighting power only when using the Area Category Method of compliance.*

[2] Specialized task work	*0.50 W/ft²*
*[3] Ornamental lighting as defined in **Section 100.1** and in accordance with **Section 140.6(c)2.***	*0.50 W/ft²*

Based on Table 140.6-C in the Energy Standards

Task Lighting Power Exclusions for Offices

An exception to **Section 140.6(a)** allows for up to 0.3 W/ft^2 of portable office lighting to be added without counting towards the LPD budget. If this option is used, Form NRCC-LTI-01-E has a section that must be completed as part of the compliance process.

Other Lighting Power Exclusions

The power used by certain lighting applications may be excluded from actual lighting power calculations. Selections from the list of exclusions including but not limited to:

- Equipment that is for sale and for demonstration
- Specialized studio lighting for video or photography that is installed in addition to general lighting
- Manufacturer-installed lighting in vending machines, refrigerated cases, walk-in freezers, and food preparation equipment

For a complete list of exclusions, see **Section 140.6(a)3** of the Energy Standards.

DETERMINING ALLOWED POWER UNDER THE COMPLETE BUILDING METHOD

Section 140.6(c)1

The Complete Building Method may only be used on projects involving buildings with one primary type of use or in mixed-use buildings or tenant spaces where 90 percent of the leased space has one primary use. This is the simplest way to determine if the lighting plan complies with the Energy Standards.

This method can only be used for building types listed in **Table 140.6-B**. The lighting power allowance is calculated by multiplying the complete building area (square feet) by the allowed lighting power density (Watt/square feet) for that building type.

PHOTO: UC SANTA BARBARA

The Benefits of Networked Controls in Office Spaces
UC Santa Barbara

In 2013, UC Santa Barbara installed network controlled LED lighting in the Student Information Systems & Technology Office through the State Partnership for Energy Efficient Demonstrations (SPEED) program. The project reduced lighting energy use by 89 percent, based on an average measured occupancy rate of 28 percent.

Each of the open office's 58 T8 fluorescent luminaires were replaced with a recessed LED luminaire and dimmable LED driver. The new luminaires were equipped with wireless occupancy sensors and wireless network lighting control units so they dim automatically when spaces are vacant. The control system software tracks energy use for the entire system and the individual luminaires. The new control system also allows for dimming, so light levels can be adjusted for specific cubicles and occupants' needs.

The occupancy data collected through the system has also proven extremely valuable, informing occupancy rate studies and decision making for HVAC retrofits and for lighting retrofits in other spaces. The occupancy data collected has also garnered better utility incentives for the campus.

Allowed Lighting Power = W/ft² from Table 140.6-B X floor area

When applying the Complete Building Method on a project where a parking garage is included, the parking structure and buildings should be calculated separately using the appropriate use type for each.

DETERMINING ALLOWED POWER UNDER THE AREA CATEGORY METHOD

Section 140.6(c)2

The Area Category Method provides a single lighting power allowance for each primary function area listed in **Table 140.6–C**. This exact value is calculated by multiplying the entire area (square feet) of each function area (including floor space used by partitions) by the allowed lighting power density (W/ft²) for that function area. The total allowed lighting power is the sum of the lighting power allotments for all the areas covered by the permit application.
Allowed Lighting Power = Watts / ft² from Table 140.6-C X entire floor area

Additional Lighting Power Allotments

Additional lighting energy use is allowed for some areas under the Area Category Method including but are not limited to:

- Adjustable or directional accent, display and feature lighting
- Decorative lighting
- Ornamental lighting
- Task lighting

DETERMINING ALLOWED POWER UNDER THE TAILORED METHOD

Section 140.6(c)3

The Tailored Method is typically used for projects that include space types listed in **Table 140.6-D** of the Energy Standards. Within nonresidential applications, these space types may include:

- Auditorium Area
- Dining Areas
- Main Entry Lobby Area
- Lounge Area
- Waiting area
- Retail

Space types, or "primary function areas," not listed in **Table 140.6-D** can refer to the Tenth Edition IES Handbook to apply the Tailored Method in other areas by obtaining an illuminance value appropriate for the tasks occurring in that area. See **Section 140.6(c)3H(i)(e)** for details.

PHOTO: LUTRON

General Lighting Power Allotments

Under the Tailored Method, general lighting power allotments are tailored to each space or area based on the dimensions of the space, including luminaire mounting height and IES-recommended illumination levels. The process includes the following steps:

1. Determine the primary function area, and the illuminance value (listed in lux) per **Table 140.6-D**
2. Determine the room cavity ratio (RCR) according to **Table 140.6-F**
3. Use the illuminance value and the RCR to find the allowed LPD according to **Table 140.6-G**

Areas with high ceilings have a high RCR, making them more difficult to light. The Tailored Method allows greater LPD allowances as the RCR increases. The RCR trigger points for increased LPD allowances start at 2.0, then increase at 3.5 and 7.0.

GENERAL LIGHTING TRADE-OFFS

The Tailored Method allows for certain LPD trade-offs for general lighting only. Trade-offs must be documented using compliance forms and must be kept within conditioned areas or within unconditioned areas. Trade-offs are allowed:

- From one conditioned area using the Tailored Method to another conditioned area using either the Tailored or Area Category Method
- From one unconditioned area using the Tailored Method to another unconditioned area using either the Tailored or Area Category Method

Additional Lighting Power Allotments

In addition to general lighting power allotments, the Tailored Method provides lighting power allotments for special tasks that use lighting as a way to draw attention to an area, by providing visual contrast to what is contributed from the general lighting. The following is a sample selection of lighting power allotments in the Energy Standards. The complete list can be found in **Section 140.6(c)3**:

- **Wall display lighting:** Supplementary lighting required to highlight features such as artwork or awards, which is displayed on perimeter walls. It provides a higher level of illuminance to a specific area than the level of surrounding ambient illuminance.
- **Ornamental/special effects lighting:** Decorative indoor luminaires are typically chandeliers, sconces, theatrical projectors, dynamic or moving lighting or illuminated colored panels that are not providing general illumination.

Room Cavity Ratio

The room cavity ratio describes the configuration of a room. Rooms with high ceilings are typically more difficult to illuminate and have a high RCR. Because luminaires are not as effective in areas with a high RCR, the Energy Standards allow a higher lighting power density.

The RCR must be calculated for any function area using the Tailored Method. **Table 140.6-F** provides the equations for the calculations. The RCR is based on the entire space bounded by floor-to-ceiling partitions. If a task area with a larger space is not bounded by floor-to-ceiling partitions, the RCR of the entire space must be used for the task area.

Room Cavity Ratio (RCR) Equations

Determine the Room Cavity Ratio using one of the following equations

Room cavity ratio for rectangular rooms

$$RCR = \frac{5 \times H \times (L + W)}{L \times W}$$

Room cavity ratio for irregularly shaped rooms

$$RCR = \frac{2.5 \times H \times P}{A}$$

H = Vertical distance from the work plane to the center line of the lighting fixture
L = Length W = Width P = Perimeter A = Area of the room

Table 140.6-F in the Energy Standards

✓ EXCEPTION: Room Cavity Ratio

*RCR allows for imaginary or virtual walls when the boundaries are established by "high stack" elements (close to the ceiling structure and high storage (shelves) or high partial walls defined as "perimeter full height partitions" described in **Section 140.6(c) 3liv**.*

In-Person Codes and Energy Standards Training

EnergyCodeAce offers training events at the investor-owned utility energy education training centers and other locations throughout California.

Have a group of 20 or more attendees that need more help to apply the Energy Standards in practice? Training sessions can also be requested and scheduled to fulfill needs not covered by the scheduled sessions.

*Submit a request at **energycodeace.com/content/training-request***

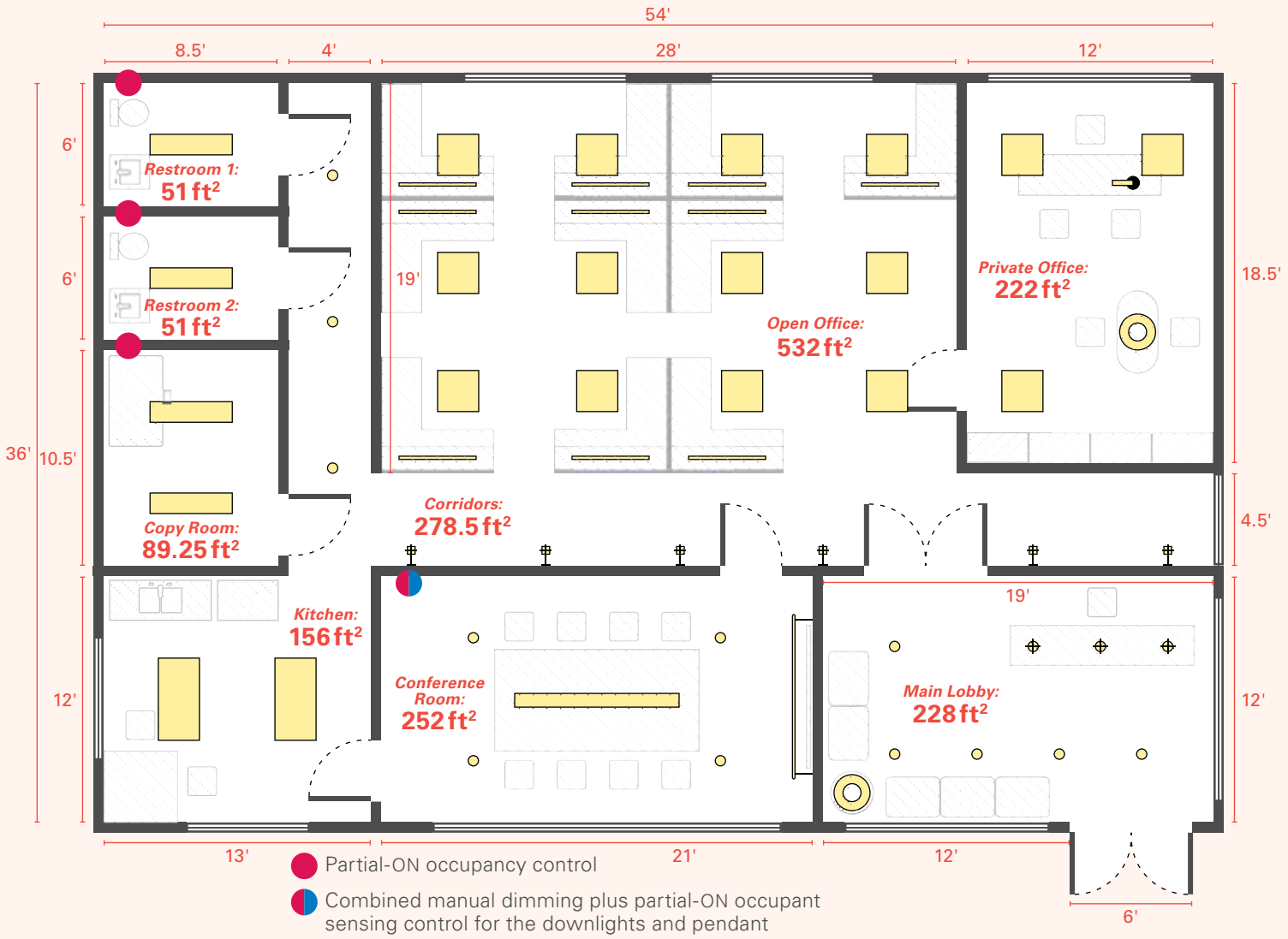
EXAMPLE: CALCULATE ACTUAL & ALLOWED LIGHTING POWER

J.S.H. Associates 1,944 square feet office building

The following example will show the steps to determine whether the actual lighting power of a project will comply with the lighting power budget allowed by the Energy Standards using the Area Category Method:

1. Calculate the lighting power allowance
2. Calculate the total installed lighting power for all planned lighting from a lighting schedule
3. Exclude portable task lighting power for the office areas, using an option available under the Area Category Method
4. Apply control credits earned by specifying lighting controls that go beyond the Energy Standards requirements
5. Determine the adjusted lighting power using answers from steps one through four
6. Compare the adjusted installed lighting power to the allowed lighting power

This section concludes with an example calculation of allowed lighting power using the Complete Building Method to compare results with the Area Category Method. The example offers notes on what sections of the Certificates of Compliance for Nonresidential Indoor Lighting are necessary to support the compliance process for this scenario.



Scale: 1/8" = 1'

Indoor Lighting Schedule

Symbol	Luminaire	Qty.	System Wattage	Total Watts	Efficacy *(Lumens / Watt)*
	2X2 LED RECESSED TROFFER Cree CR22	15	35	525	90 – 100
	1x4 1-LAMP FLUORESCENT RECESSED TROFFER Finelite HPR w/ Sylvania 32W T8 lamp; Sylvania Quicktronic Ballast	4	28	112	89
	2x4 2-LAMP FLUORESCENT RECESSED TROFFER Finelite HPR w/ Sylvania 32W T8 lamp; Sylvania Quicktronic Ballast	2	54	108	89
	8' LED SUSPENDED LUMINAIRE Lunera Lighting L7-G3	1	85	85	84
	8' LED LINEAR WALL MOUNT LUMINAIRE Finelite Muro-Oval	1	45.2	45.2	57.3
	6" LED RECESSED DOWNLIGHT Cree CR6	12	12	144	90
	LED WALL SCONCE Tech Lighting Mura	6	8	48	50
	LED PENDANT Philips Vetro	3	10	30	76
	LED SUSPENDED LUMINAIRE Philips Ledino Cinta Suspension Light	2	22.5	45	100
			Total Installed Lighting Watts : 1,142.2 W		
PORTABLE LIGHTING					
	45" LED UNDERCABINET TASK LIGHTING Finelite Edge Undercabinet	10	12.2	122	62.2
	LED TASK LIGHT Koncept Z Bar Mini Task Light	1	6.5	6.5	—
			Total Portable Lighting Watts: 128.5 W		

The schedule is used to fill in lighting schedule in Form NRCC-LTI-01-E

TOTAL WATTS: 1,270.7 W

NRCC-LTI-01-E: Indoor Lighting, "C. Indoor Lighting Schedule and Field Inspection Energy Checklist"

STATE OF CALIFORNIA
INDOOR LIGHTING
CEC-NRCC-LTI-01-E (Revised 04/18)
CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF COMPLIANCE	NRCC-LTI-01-E
Indoor Lighting	(Page 5 of 6)
Project Name:	Date Prepared:

A Separate Lighting Schedule Must Be Filled Out for Conditioned and Unconditioned Spaces. Installed Lighting Power listed on this Lighting Schedule is only for:
☐ CONDITIONED SPACE ☐ UNCONDITIONED SPACE

H. Indoor Lighting Schedule and Field Inspection Energy Checklist

Luminaire Schedule		Installed Watts				Location	Field Inspector
01	02	03	04	05	06	07	08
Name or Item Tag	Complete Luminaire Description (i.e. 3 lamp fluorescent troffer, F32T8, one dimmable electronic ballast)	Watts per Luminaire	How wattage was determined: CEC Default from NA8	How wattage was determined: According to §130.0(c)	Number Luminaires	Total Installed Watts in this area (03 x 05)	Primary Function area in which these luminaires are installed	Pass	Fail
			☐	☐		0		○	○
			☐	☐		0		○	○
			☐	☐		0		○	○
			☐	☐		0		○	○

DETERMINING COMPLIANCE WITH THE AREA CATEGORY METHOD

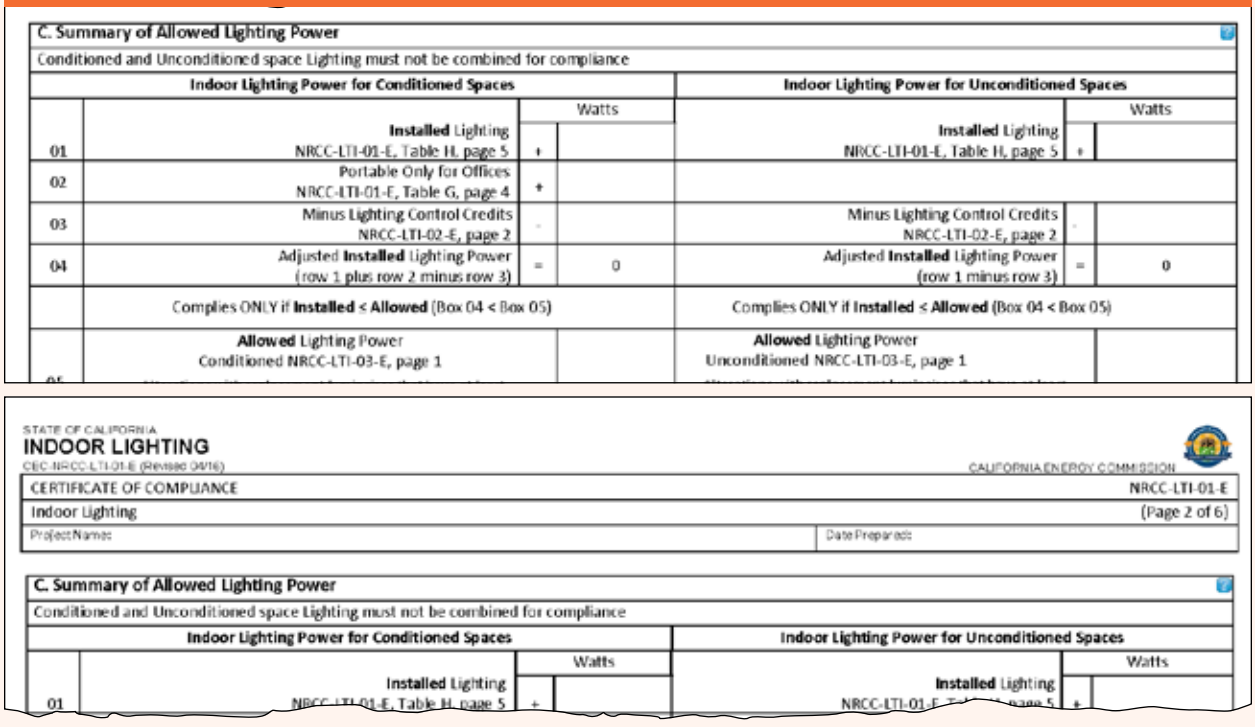
The lighting plan complies if the total installed lighting power is less than or equal to the allowed lighting power. This example uses the Area Category Method to determine allowed lighting power. Area by area, the lighting power of the spaces within the building is calculated. All areas in the project are added together. If the total lighting power is greater than the Energy Standards allow, the lighting design does not comply and it will have to be revised to achieve a lower lighting power. The Summary of Allowed Lighting Power, shown below, will be completed at the end of this example.

Summary of Allowed Lighting Power

Installed Lighting (NRCC-LTI-01-E)	**+**	
Portable Lighting (NRCC-LTI-01-E)	**+**	
Minus Lighting Control Credits (NRCC-LTI-02-E)	**–**	
Adjusted Installed Lighting Power	**=**	
Complies ONLY if Installed ≤ Allowed		
Allowed Lighting Power (NRCC-LTI-03-E)		

Adapted from "Summary of Allowed Lighting Power," Form NRCC-LTI-01-E: Indoor Lighting

NRCC-LTI-01-E: Indoor Lighting, "C. Indoor Lighting Schedule and Field Inspection Energy Checklist"



C. Summary of Allowed Lighting Power

Conditioned and Unconditioned space Lighting must not be combined for compliance

	Indoor Lighting Power for Conditioned Spaces		Watts	Indoor Lighting Power for Unconditioned Spaces		Watts
01	**Installed** Lighting NRCC-LTI-01-E, Table H, page 5	+		**Installed** Lighting NRCC-LTI-01-E, Table H, page 5	+	
02	Portable Only for Offices NRCC-LTI-01-E, Table G, page 4	+				
03	Minus Lighting Control Credits NRCC-LTI-02-E, page 2	-		Minus Lighting Control Credits NRCC-LTI-02-E, page 2	-	
04	Adjusted **Installed** Lighting Power (row 1 plus row 2 minus row 3)	=	0	Adjusted **Installed** Lighting Power (row 1 minus row 3)	=	0
	Complies ONLY if **Installed** ≤ **Allowed** (Box 04 < Box 05)			Complies ONLY if **Installed** ≤ **Allowed** (Box 04 < Box 05)		
05	**Allowed** Lighting Power Conditioned NRCC-LTI-03-E, page 1			**Allowed** Lighting Power Unconditioned NRCC-LTI-03-E, page 1		

STATE OF CALIFORNIA
INDOOR LIGHTING
CEC-NRCC-LTI-01-E (Revised 04/16)
CALIFORNIA ENERGY COMMISSION

CERTIFICATE OF COMPLIANCE	NRCC-LTI-01-E
Indoor Lighting	(Page 2 of 6)
Project Name	Date Prepared

C. Summary of Allowed Lighting Power

Conditioned and Unconditioned space Lighting must not be combined for compliance

	Indoor Lighting Power for Conditioned Spaces		Watts	Indoor Lighting Power for Unconditioned Spaces		Watts
01	**Installed** Lighting NRCC-LTI-01-E, Table H, page 5	+		**Installed** Lighting NRCC-LTI-01-E, Table H, page 5	+	

1 Lighting Power Allowance

1. There are six primary function areas in this space. Determine the allowed lighting power density of each area according to **Table 140.6-C**.
2. Determine the size (square feet) of each area type.
3. Calculate the wattage allowance by multiplying the square feet of the each area type by the allowed lighting power density.
4. Total the allowed watts.

Form NRCC-LTI-03-E: Indoor Lighting Power Allowance

C-2 Area Category Method General Lighting Power Allowance

Primary Function Area	Allowed Lighting Power	x	Area	=	Allowed Watts
Office Area >250ft²	0.75W/ft²		532 sqft		399W
Office Area ≤250ft²	1.0W/ft²		222 sqft		222W
Classroom, Lecture, Training, Vocational Area	1.2W/ft²		252 sqft		302.4W
Lobby	.95W/ft²		228 sqft		216.6W
Kitchen, Food Prep Area	1.2W/ft²		156 sqft		187.2 W
Corridor, Restroom, Stair and Support Area	0.6W/ft²		470.02 sqft		282W
				TOTAL	**1,609.2W**

Some of the areas in the example are eligible for an additional wattage allowance for specialized lighting. The footnotes in **Table 140.6-C** are used to determine how much can be allocated. This is a "use it, or lose it" allowance. If there is no lighting in the schedule that qualifies for the additional allowance, it cannot be used.

Additional Lighting Wattage Allowance

The suspended luminaire in the lobby is classified as "Ornamental lighting," as defined in **Section 100.1** and in accordance with **Section 140.6(c)2**. The whiteboard lighting in the conference room also qualifies for an additional lighting wattage allowance according to **Table 140.6-C**.

Form NRCC-LTI-03-E: Indoor Lighting Power Allowance

C-3 Area Category Method Additional Lighting Wattage Allowance

1. Determine the additional watts allowed according to the footnotes in **Table 140.6-C**.
   Ornamental Lighting: **0.5 W / ft²**
   Whiteboard Lighting: **5.5 W per linear foot**
2. Determine the square feet of the lobby area.
   For white board lighting, determine the linear feet of whiteboard.
   Ornamental Lighting: **228 square feet**
   Whiteboard Lighting: **7 feet**
3. Calculate the additional wattage allowance for ornamental and whiteboard lighting by multiplying the square footage or linear feet by the additional wattage per allowance. Compare to the specified fixture for both scenarios
   Ornamental Lighting: **114 W (Specified Fixture 22.5)**
   Whiteboard Lighting: **38.5 W (Specified Fixture 45.2)**
4. Choose the smaller of either the newly calculated allowed watts or the total design watts of the luminaire.
   There are 22.5 W for ornamental lighting and 38.5 W for whiteboard lighting, totaling 61 W of additional allowed lighting wattage.

2

Total Lighting Power Allowances

C-1 Area Category Method Total Lighting Power Allowances

Calculate the total lighting power allowance by adding the additional lighting wattage allowance to the general lighting power allowance.

1,609.2W + 61W = 1,670.2 W

Allowed Lighting Power (NRCC-LTI-03-E)	-	**1,670.2 W**

Installed Lighting Power

The installed lighting power includes all planned permanent and portable lighting. Complete the lighting schedule in "C. Indoor Lighting Schedule and Field Inspection Energy Checklist" to determine the total to use for compliance purposes.

Form: NRCC-LTI-01-E: Indoor Lighting

C. Indoor Lighting Schedule and Field Inspection Energy Checklist

Installed Lighting (NRCC-LTI-01-E)	+	**1,270.7 W**

3 Installed Portable Luminaires in Offices

When calculating actual lighting power, there is an exception to **Section 140.6(a)** that states that up to 0.3 watts per square foot of portable lighting for office areas shall not be required to be included in the calculation of actual indoor Lighting Power Density. When calculating installed lighting power under the Area Category Method, planned portable luminaires should be calculated using "G. Installed Portable Luminaires in Offices—Exception to Section 140.6(a)" in **Form NRCC-LTI-01-E**. For the Complete Building Method, include the total wattage for portable lighting into the installed lighting total.

Using **Form NRCC-LTI-01-E**, calculate the wattage for installed portable luminaires in offices. This section should only be filled out for portable luminaires in offices as defined by **Section 100.1** All other planned portable luminaires should be documented on "C. Indoor Lighting Schedule and Field Inspection Energy Checklist." This section is used to determine if greater than 0.3 W of portable lighting is planned for any office.

There are two portable luminaires in the offices—LED undercabinet lighting for the cubicles in the open office and an LED task light in the private office.

1. Multiply the watts per luminaire by the number of luminaires to determine installed portable luminaire watts in this office.
   LED Undercabinet: **122 W** LED Task Light: **6.5 W**
2. Determine the square feet of each office primary function area.
   Open Office: **532 ft²** Private Office: **222 ft²**
3. Divide the installed portable luminaire watts by the square feet of the office to determine watts per square foot.
   LED Undercabinet: **122 W ÷ 532 ft² = 0.23 W/ft²**
   LED Task Light: **6.5 W ÷ 222 ft² = 0.03 W/ft²**
4. Determine accountable wattage by multiplying the square feet of the office primary function area by the watts per square feet. If the watts per square foot is ≤ 0.3, claim 0 W of accountable watts for installed portable luminaires.
   LED Undercabinet Task: **0 W** LED Task Light: **0 W**

Portable Lighting (NRCC-LTI-01-E)	**+**	**0 W**

The new Installed Lighting total with the exclusion of portable luminaire wattage is:

Installed Lighting (NRCC-LTI-01-E)	**+**	**1,270.7 W**

G. Installed Portable Luminaires in Offices—Exception to Section 140.6(a)

4 Lighting Control Credits

The lighting plan must be evaluated for potential lighting control credits that can be used as a power adjustment factor in your calculations.

Lighting control requirements that are mandatory **(Section 130.1)** do not qualify for a control credit, only Lighting Power Adjustment Factors listed in **Table 140.6-A**. This lighting design is not eligible for any of the 2016 Power Adjustment Factors.

Lighting Control Credits (NRCC-LTI-02-E)	-	**0 W**

5 Adjusted Lighting Power

Use the "Summary of Allowed Lighting Power" in **Form NRCC-LTI-01-E** to calculate the adjusted installed lighting power by adding the portable lighting and subtracting the lighting control credits from the total installed lighting.

1270.7 W + 0 W - 0 W = 1270.7 W of adjusted lighting power

6 Compare Adjusted Installed Lighting Power to Allowed Lighting Power

Use the "Summary of Allowed Lighting Power" in **Form NRCC-LTI-01-E** to determine if this lighting schedule is compliant.

Summary of Allowed Lighting Power

Installed Lighting (NRCC-LTI-01-E)	+	**1,270.7 W**
Portable Lighting (NRCC-LTI-01-E)	+	**0 W**
Minus Lighting Control Credits (NRCC-LTI-02-E)	–	**0 W**
Adjusted Installed Lighting Power	=	**1,270.7 W**
Complies ONLY if Installed ≤ Allowed		
Allowed Lighting Power (NRCC-LTI-03-E)	**1,670.2 W — This space complies.**	

Adapted from "Summary of Allowed Lighting Power," Form NRCC-LTI-01-E: Indoor Lighting

COMPLETE BUILDING METHOD

Form NRCC-LTI-03-E: Indoor Lighting Power Allowance

B. Complete Building Method Lighting Power Allowance

The Complete Building Method can be used for select building types, including office buildings. To evaluate whether the space complies, calculate the allowed lighting power by multiplying square footage by one lighting power density for the whole project and compare it to the actual lighting power.

Lighting Power Allowance

The Complete Building Method may only be used in projects involving entire buildings with one primary use, or in mixed-use buildings or tenant spaces where 90 percent of the spaces have one primary use.

The schedule includes portables, but under the Complete Building Method the total wattage used by the portables goes into total installed lighting power and no exemption can be applied.

According to **Table 140.6-B**, this space is classified as an office building.

1. Determine the allowed lighting power density of an office building according to **Table 140.6-B**
   Office Building: **0.8 W/ft²**
2. Multiply the allowed lighting power density by the area of the space.
   0.8 W/ft² X 1,944 ft² = 1,555.2 W allowed lighting power under the Complete Building Method

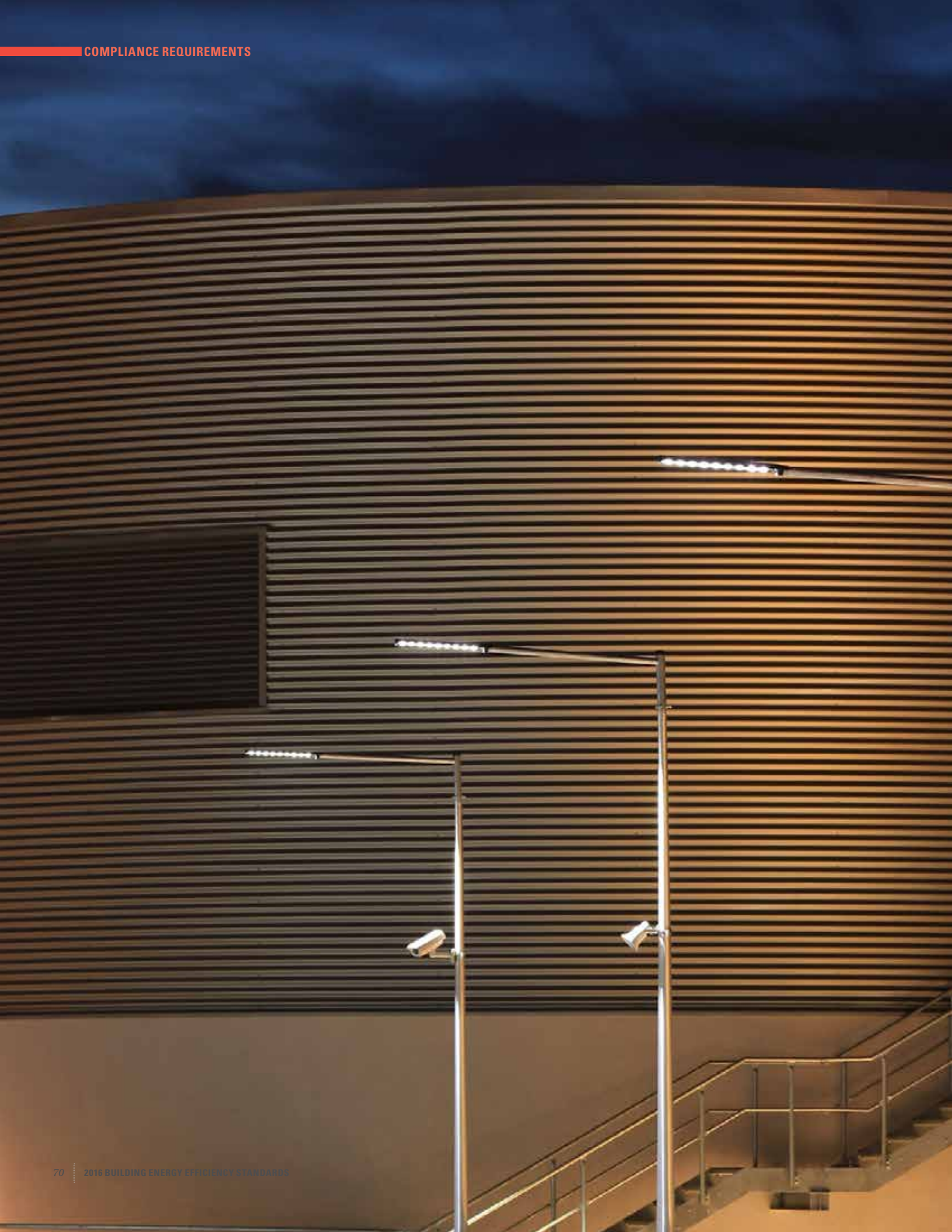
Determining Compliance Under the Complete Building Method

Use the "Summary of Allowed Lighting Power" in **Form NRCC-LTI-01-E** to determine if this lighting schedule is compliant under the Complete Building Method.

Summary of Allowed Lighting Power

Installed Lighting (NRCC-LTI-01-E)	**+**	**1,270.7 W**
Portable Lighting (NRCC-LTI-01-E)	**+**	**—**
Minus Lighting Control Credits (NRCC-LTI-02-E)	**–**	**0 W**
Adjusted Installed Lighting Power	**=**	**1,270.7 W**
Complies ONLY if Installed ≤ Allowed		
Allowed Lighting Power (NRCC-LTI-03-E)		**1,555.2 W — This space complies.**

Adapted from "Summary of Allowed Lighting Power," Form NRCC-LTI-01-E: Indoor Lighting



PRESCRIPTIVE REQUIREMENTS FOR OUTDOOR LIGHTING

The prescriptive requirements for outdoor lighting apply only to hardscape areas. A lighting installation is in compliance if its installed lighting power is less than the allowed lighting power for the site. The Energy Standards specify different lighting power allowances for different lighting zones. Continuous lighting in Zone 0 is now explicitly prohibited, however, sites may utilize a single 15W or less luminaire at entrances to parking lots.

	LZ0	LZ1	LZ2	LZ3	LZ4
Area Wattage Allowance (AWA) The total illuminated hardscape area included in the project multiplied by the AWA for the lighting zone.	Not Applicable	0.020 W/ square feet	0.030 W/ square feet	0.040 W/ square feet	0.050 W/ square feet
Linear Wattage Allowance (LWA) The total perimeter length of the hardscape included in the project multiplied by the LWA for the lighting zone appropriate to the project. The total hardscape perimeter does not include areas that are not illuminated.	Not Applicable	0.15 W/lf	0.25 W/lf	0.35 W/lf	0.45 W/lf
Initial Wattage Allowance (IWA) An additional power allowance for small sites or unusual hardscape geometries. The IWA value for the project's lighting zone is added—only once—to the total lighting power allowance for a site.	Not Applicable	340 W	450 W	520 W	640 W

Adapted from Table 140.7-A in the Energy Standards

Calculating Allowed Lighting Power

GENERAL HARDSCAPE LIGHTING ALLOWANCE + ADDITIONAL LIGHTING POWER ALLOWANCES

Identify which lighting zone the project falls under (LZ0–LZ4), and if the project site is subject to any local ordinances that exceed Title 24, Part 6 requirements. Use the plan view for all area and distance measurements, unless otherwise noted:

1. Calculate the illuminated hardscape area: This area is square, centered on each luminaire or pole, and is 10 times the luminaire mounting height. Subtract from this any areas within the square that are within a building, obstructed by a structure, beyond the hardscape area, or beyond property lines. Also subtract any planters or landscape areas larger than 10' x 10'.
2. Determine the general hardscape lighting allowance: Multiply the illuminated hardscape area (from Step 1) by the area wattage allowance (AWA) for the appropriate lighting zone (see "Lighting Power Allowances" table).
3. Calculate the perimeter length and linear wattage allowance (LWA): Multiply the hardscape perimeter by the LWA for the appropriate lighting zone (see "Lighting Power Allowances" table).
4. Find the total general hardscape lighting allowance: Add the allowed wattage from steps 2 and 3. This total is the general hardscape lighting allowance for the illuminated hardscape area.
5. Add any additional lighting power allowances for specific applications: Check **Table 140.7-B** (see appendix) for any additional lighting power allowances that apply, and add these to the sum from step 4.
6. Add the initial wattage allowance (IWA). The IWA for the project lighting zone (listed in "Lighting Power Allowances") can be added to the site's total lighting power allowance—but just once for the entire site.

PHOTO: CLTC, UC DAVIS

Factors That Affect Lighting Power Allowances

The number of luminaires, their mounting heights and their layout affect the size of the illuminated area, and this size, in turn, affects the allowed lighting power.

Calculating Actual Lighting Power

Add the wattage of all non-exempt lighting systems (including ballast, driver or transformer losses) to determine the actual installed lighting power (W) of an installation and ensure it is less than the allowed lighting power.

Luminaire Classification by Rated Power

Section 130.0(c)

In some cases, the standards consider the maximum rated power of a luminaire instead of the amount of energy used by a lamp inside of that luminaire. For example, a luminaire that can accommodate a 100W incandescent lamp is considered a 100W luminaire for compliance purposes, even if it uses a 20W LED lamp.

Additional Lighting Power Allowances

Specific outdoor lighting applications merit additional lighting power allowances only if lighting for the specific application is installed. These vary depending on which lighting zone the project is associated with (see appendix). Allowed lighting power for specific applications cannot be added to the total power allowance unless lighting for that specific application is installed. The additional allowance for specific applications is the smaller of that allowed in **Table 140.7-B** or the installed lighting for the specific application.

Planters and Small Landscape Areas

Planters and landscape areas are included in general hardscape area calculations if:

1. Less than 10 ft wide or 10 ft long AND
2. Bordered on at least three sides by hardscape

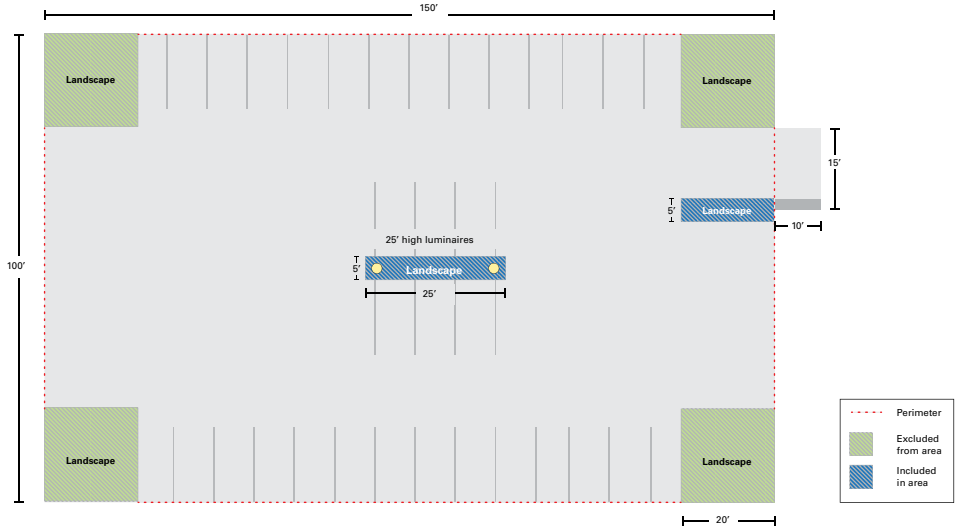
NOTE: Planters and landscape areas are excluded from general hardscape area calculations if they are greater than 10 ft in both width and length. Perimeters of excluded areas may be included in calculation of the Linear Wattage Allowance (LWA).

EXAMPLE EXERCISE: CALCULATING THE POWER ALLOWANCE FOR A PARKING LOT

Scenario

An outdoor parking lot 15,000 square feet in size is located in a commercial area categorized as Lighting Zone 3. Two 300W luminaires are mounted at a height of 25' in a 5'x25' island in the middle of the lot. The parking lot has 20' x 20' landscaped areas in each corner.

What is the total power allowance for this parking lot? Does the lighting comply with Title 24, Part 6?



Steps

1. Calculate the illuminated hardscape area, remembering to subtract any landscape areas over 10' x 10': The illuminated area for each 25' pole is 250'x250', so it extends beyond the actual hardscape of the parking lot and encompasses the 150 square feet entrance. Because the lot is not adjacent to other hardscape on the site, use the 15,000 square feet area of the lot itself, adding the 15'x10' entrance and subtracting the four 400 square feet landscaped corners of the lot:
   15,000 ft² +150 ft² –1,600 ft² =13,550 ft²
2. Determine the general hardscape lighting allowance. Multiply the illuminated hardscape area (Step 1) by the AWA for LZ3 (found in **Table 140.7-A**):
   13,550 ft² x 0.04 W/ft² = 542 W
3. Calculate perimeter length and linear wattage allowance. Multiply the hardscape perimeter by the LWA (listed by lighting zone in **Table 140.7-A):**
   520ft x 0.34W/lf = 176.8W
4. Add the power allowances determined in steps 2 and 3:
   542W + 176.8W = 718.8W
5. Add any additional lighting power allowances for specific applications:
   None are listed in Table 140.7-B for this example.
6. Add the IWA—only once for the entire site. The IWA for a site in LZ3 is listed in **Table 140.7-A** as 520 W:
   718.8W + 520W = 1,238.8W

Answer

Total power allowance for this hardscape area: 1,238 W.

YES — the lighting installation complies. The parking lot luminaires use a total of 600 watts, which is far less than the allowed. A more energy-efficient option, such as a 110W LED luminaire (220W total), could further improve the energy efficiency of this installation.

SIGN LIGHTING MANDATORY REQUIREMENTS

Section 130.3

MANDATORY REQUIREMENTS

All indoor sign lighting must be equipped with an automatic time-switch control **OR** an astronomical time-switch control.

All outdoor sign lighting must be equipped with a photocontrol AND an automatic time-switch control **OR** an astronomical time-switch control.

EXCEPTIONS

Signs inside tunnels and large, permanently covered outdoor areas that operate 24 hours per day, 365 days per year.

Signs Illuminated Night and Day

All outdoor signs ON during the day and night must be equipped with a control that can automatically reduce lighting power at least 65 percent at night. This applies to signs illuminated for more than one daylight hour in addition to nighttime hours.

EXCEPTIONS

Signs inside tunnels and large, permanently covered outdoor areas that operate 24 hours per day, 365 days per year.

Demand Responsive Electronic Message Centers (EMCs)

Any EMC with a connected lighting power load greater than 15 kW must have a control that can reduce lighting power by at least 30 percent in response to a demand response (DR) signal.

HEALTH & SAFETY EXCEPTION

EMCs that must remain at full lighting power due to health or safety regulations are exempt and not required to respond to DR signals.


PHOTO: LUNERA

PRESCRIPTIVE REQUIREMENTS FOR SIGNS

Section 140.8

In addition to the mandatory requirements for signs, under the prescriptive compliance approach all internally and externally illuminated signs must use approved sources or comply with maximum allowed lighting power limits.

Compliant Sources

Section 140.8(b)

Signs equipped strictly with one or more of the following source types do not need to adhere to allowed lighting power limits:

- **High-pressure sodium (HPS)** lamps
- **Metal halide (MH)** lamps that are pulse start or ceramic with a minimum ballast efficiency of 88 percent OR pulse-start MH lamps using no more than 320 W, but not 250W or 175W lamps, with a minimum ballast efficiency of 80 percent
- **Neon or cold cathode** lamps with a minimum transformer or power supply efficiency of at least 75 percent for a rated output current less than 50 mA OR a minimum efficiency of 68 percent when the rated output current is 50mA or greater
- **Fluorescent** lighting systems that only use lamps with a minimum CRI of 80 OR use electronic ballasts with a fundamental output frequency of at least 20 kHz
- **LEDs** with a power supply efficiency of at least 80 percent
- **CFLs** that do not use medium screw-base sockets

Maximum Allowed Lighting Power

Section 140.8(a)

Signs with non-compliant source types must adhere to these lighting power limits:

- **Internally Illuminated Signs: 12W/ft² of the illuminated sign area**
  For double-faced signs, count the area of just one face. Luminaires with permanently installed ballasts or transformers: Use the operating input wattage of the lamp/ballast or lamp/transformer combination.
- **Externally Illuminated Signs: 2.3W/ft² of the illuminated sign area**
  Luminaires with permanently installed ballasts or transformers: Use the operating input wattage of the lamp/ballast or lamp/transformer combination.

Sign Alterations

Section 141.0(b)2M

Certain alterations to existing signs, whether internally or externally illuminated, require compliance with the 2016 Energy Standards for sign lighting (**Section 140.8**):

1. The connected lighting load is increased
2. Over 50 percent of the ballasts are replaced and rewired
3. The sign is relocated, either on the same site or to a new site

ADDITIONS, REPAIRS & ALTERATIONS

Additions

Section 141.0(a)

Lighting plans for building additions must meet the same mandatory and prescriptive or performance standards as lighting installed for a new construction project. If the performance approach is followed, the LPD for the general lighting systems may be traded off with other building features.

Alterations

Requirements for indoor lighting alterations **(S141.0(b)2I-J)** are categorized into three types of alterations.

- Entire Luminaire Alterations
- Luminaire Component Modifications
- Lighting Wiring Alterations

It is important to note that the following project scenarios are exempt from lighting alteration requirements:

- Modification (replacement or installation) of two or fewer luminaires in an enclosed space.
- Projects that may disturb asbestos.

The lighting power density requirements established in **section 140.6** and the control requirements in **Table 141.0-E** are for entire luminaire alterations and luminaire component modifications and must be met unless the reduction in power from the existing design warrants use of the new third compliance path. This new third compliance path allows for reduced control requirements (area and shut-off only) for occupancy types based on their reduced installed, lighting power as compared to the existing system:

- For office, retail and hotels that reduce lighting power by a minimum of 50 percent of the existing system the required controls are reduced to area controls and shut-off controls.
- For all other occupancies that reduce lighting power by a minimum of 35 percent of the existing systems the required controls are reduced to area controls and shut-off controls.

For lighting designs that use more than 85 percent of the allowed LPD established using the Area Method, most controls are required. For designs using 85 percent or less of the allowed LPD, daylighting and demand response controls are no longer required.

Indoor Lighting Alterations

Alteration	Scope of Work
Entire Luminaire Alterations (§141.0(b)2I.)	• Remove & reinstall existing luminaires • Remove existing luminaires, replace with new • Add new luminaires • Adding, removing or replacing ceiling or walls along with any redesign of the lighting system
Luminaire Component Modifications (§141.0(b)2J.)	• Lamp and ballast/ driver replacement • Permanently changing the light source type in an existing luminaire • Changes to the luminaire's optical system
Lighting Wiring Alterations (§141.0(b)2K.)	• New circuits • Replace, modify, or relocate wiring between a switch and a luminaire • Replace, modify or relocate wiring between a panelboard and a luminaire • Replacement of existing lighting control panels, panelboards or branch circuiting with new

Entire Luminaire Alterations

For projects that consist of one of the following scenarios:

- Removing and reinstalling at least 10 percent of the existing luminaires
- Replacing or adding luminaires
- Adding, removing, or replacing walls or ceilings

Luminaire Component Modifications

Luminaire component modifications requirements apply to projects where one of the following apply:

- Replacement of ballast/driver AND light source
- Permanently changing the light source in a luminaire
- Changing the optical system of the luminaire

To trigger the luminaire component modification requirements, at least 70 existing luminaries need to be modified per floor or tenant space in a single year.

It is important to note that lamp replacements alone and ballast/driver replacements alone do not trigger these requirements so long as the replacement does not require modification of the luminaire to install and power the new device.

Compliance Requirements for Lighting Alterations

Applicable Section 130.1 Control requirements	Control Requirements for Lighting Alterations		
	Resulting lighting power, compared to the lighting power allowance specified in Section 140.6(c)2, Area Category Method		Option 3 Lighting power is reduced by 35/50% compared to existing[1]
	Option 1 Lighting power is >85% to 100% of allowance	Option 2 Lighting power is ≤85% of allowance	
Section 130.1(a)1, 2, and 3 Area Controls	Yes	Yes	Yes
Section 130.1(b) Multi-Level Lighting Controls - only for alterations to general lighting of enclosed spaces 100 square feet or larger with a connected lighting load that exceeds 0.5 watts per ft^2	Yes	For each enclosed space, minimum one step between 30-70 percent of lighting power regardless of luminaire type, or meet Section 130.1(b)	Not Required
Section 130.1(c)	Yes	Yes	Yes[2]
Section 130.1(d)	Yes	Not Required	Not Required
Section 130.1(e) Demand Responsive Controls - only for alterations >10,000 ft^2 in a single building, where the alteration also changes the area of the space, or changes the occupancy type of the space, or increases the lighting power	Yes	Not Required	Not Required

[1] Option 3 is only applicable to entire luminaire alterations and luminaire component modifications. Option 3 cannot be used for alterations where walls are moved (remodels) or where connected load is added.

[2]As bi-level controls are not required for this option, partial-off controls are not required to be installed in place of "full off" automatic shutoff controls for library book stack aisles, corridors and stairwells (see Section 141.0(b)2Iii and Jii)

Based on Table 3 in Blueprint 117

NOTE:

- Bi-level lighting controls must provide reasonably uniform illumination.
- Controls and equipment must comply with applicable mandatory requirements (per **Section 110.9**) and be installed according to manufacturers' instructions, per **Section 130.0(d)**.

Lighting Wiring Alterations

For new circuits; replacement/modifications/relocation of wiring between switch and luminaire; replacement/modification/relocation of wiring between a panelboard and luminaire; and replacement of existing lighting control panels, panelboards, or branch circuiting with new, the following requirements from **§141.0(b)2K** apply:

- Meet LPD requirements in **Section 140.6**
- Meet control requirements for area controls and automatic shut-OFF controls
- Be wired to create a minimum step between 30-70 percent of the lighting power, or meet multi-level requirements per enclosed space
- For enclosed spaces with wire alterations of at least 10 luminaires for general illumination within the primary sidelit daylit zone or the skylit daylit zone, meet the automatic daylighting control requirements

Maintenance & Repairs

No compliance measures required: Routine maintenance and repairs of lighting components, systems or equipment already installed in an existing building do not trigger Energy Standards.

The Energy Standards define maintenance tasks and repairs as:

- Lamp replacements
- Ballast replacements
- Replacement of lamp holders or lenses
- Maintenance measures that do not increase energy consumption of the equipment being serviced
- Alterations caused directly by the disturbance of asbestos
- When less than 70 luminaires are upgraded or modified within a 12-month period in a building space, it is treated as a repair rather than an alteration, per **Section 141.0(b)2J**.

PHOTO: LUNERA

CHAPTER 5

REQUIREMENTS AND RECOMMENDATIONS

DESIGNING TO CODE

The Energy Standards allow designers and builders to choose from a variety of lighting strategies and technologies. Options are available across a broad range of price points and can suit a variety of aesthetics. The sample lighting designs presented here represent just some of the many possibilities on the market today.

MINIMIZE LIGHTING POWER DENSITY, MAXIMIZE CONTROL

Designing nonresidential buildings to meet or exceed the Energy Standards requires implementing measures that maximize adaptive lighting controls to achieve the lowest lighting power density and reduce energy use. These energy efficiency steps are necessary for California to meet its ambitious goal for all new commercial buildings to be zero net energy (ZNE) by 2030. A ZNE building produces as much energy on-site as it consumes annually.

Lighting should help workers perform their tasks effectively and comfortably. In most office applications, this involves maximizing illumination while minimizing the visibility of light sources to allow employees to focus on the workspaces being lit than the lighting itself. Energy savings can be achieved while maintaining the quality of lighting for occupants' comfort and satisfaction.

A critical step in lighting design is determining the visual needs of the space and identifying the type of lighting to use. That will help in deciding which energy efficient lighting technologies and control strategies to use.

Here we will discuss how the Energy Standards apply to ambient lighting, task lighting, daylighting, and transitional spaces and provides recommendations for designing with them for nonresidential applications.


PHOTO: ACUITY BRANDS

Architecture

Lighting can emphasize, soften or balance certain architectural features, from making a small boutique feel more spacious to playing up (or playing down) the texture of a wall or accenting coves and valances. It is also helpful to consider the materials used in the space. Dark, polished granite will reflect light differently than wood or brick.

Atmosphere

Consider what activities or tasks will take place in different areas. High-contrast lighting is often used in more upscale boutiques while higher, more uniform light levels are commonly found in big box retail stores and similar outlets to support high-volume sales tasks.

Aesthetics

The style of the lighting design should complement the store's style. It should suit its demographic, whether it is classic or contemporary aesthetic, youthful or sophisticated, cutting-edge or family-oriented.

Light source choices should include the careful consideration of an appropriate CCT and color rendering ability to showcase products. Recently, the ability to adjust the CCT in-situ as seasonal displays change has become an option for retailers to consider. This category of products shows promise to adjust intensity and color, and offers a way to change the visual appearance of the space and product from a mobile device at any time.

APPLYING REQUIREMENTS FOR LIGHTING IN PRACTICE: OFFICE LIGHTING

Layered Lighting

Many nonresidential spaces traditionally rely on a lighting design approach referred to as general lighting, where ceiling-mounted luminaires provide an overall level of illumination intended to be sufficient for all space uses. This strategy results in the level of illumination being sufficient for tasks in all locations, regardless of whether tasks are being performed or not. Studies have shown that reducing ambient lighting and using localized light for specific visual tasks creates a more comfortable experience and can significantly reduce energy use.

In partnership with lighting manufacturers and the Energy Commission's Public Interest Energy Research (PIER) Program, CLTC evaluated the benefits of a layered lighting design for office applications. The studies found that including LED-based task lighting in the primary layer of lighting in offices resulted in a 50 percent savings in lighting energy and overwhelming user satisfaction. Following is a summary of some of the research conducted:

INTEGRATED LIGHTING SYSTEM

Task/ambient lighting, an effective strategy to illuminate office spaces, is a total systems approach. Dimmable overhead troffers or pendants provide the majority of the lighting, supplemented by vertical surface and task lighting. This approach achieves significant energy savings by reducing the overhead lighting load without sacrificing user comfort and visual acuity. Incorporating high quality task lighting makes this possible.

THE BENEFITS OF LED TASK LIGHTING

The "Portable Office Lighting Systems Final Report" summarized research to design, develop, and test prototype portable workstation luminaires and implemented lighting controls in these lamps to provide both workstation and office-level lighting control.

"Developing Lighting Technologies Integrated Office Lighting":
finelite.com/products/pls-overview

Compliance Requirements

Lighting power density maximums for most office-related areas are now below 1 W/ft^2. The required maximums or lower LPDs can be achieved by carefully using only what is needed and by using LED technologies where possible. Review **Table 140.6-C** for the allowed lighting power allowances in the Area Category Method primary function area.

Recommendations

1. **Visual Comfort and Uniformity:** designing lighting for office spaces, use indirect lighting to minimize glare on computer screens and task lighting to provide users light when and where it is needed. Indirect lighting illuminates the ceiling, which in turn reflects light down to the vertical surfaces, task areas and floor. If the lighting design provides uniform distribution, the resulting illumination can be diffuse, soft and nearly shadow-free.
2. **Vertical Illumination:** Adding lighting for vertical surfaces where the task/ambient strategy is applied reduces contrast ratios and gives the space a softer and more appealing visual appearance. This additional effect also offers energy reduction opportunities when the luminaires illuminating the vertical surfaces are controlled in a separate lighting layer. This layer can be dimmed or shut off during typically vacant periods or during a demand response event.
3. **Networked Controls:** In an open office environment, overhead ambient lighting is typically controlled in large zones. As a result, large areas of a building may be illuminated for long periods of time, regardless of occupancy. Significant energy and maintenance savings can be achieved by using a combination of low ambient lighting, zonal controls for smaller areas and high-quality task lighting and personalized controls Many controls solutions involve connecting all light points into a network using either wired or wireless communication between sensor and luminaires, or from luminaire to luminaire if integrated controls are used. Not all networked systems accurately collect information about energy use. Some systems do not collect or store any information and are intended to function as a hardware-based system only.

   The Energy Standards do not require that networked lighting controls be used to meet the mandatory measures. However, many current systems have standard features that meet and exceed the measures in **Section 130.1** and will help to comply with the new Electric Power Distribution Systems requirements in **Section 130.5**.


PHOTO: CORELITE

MANAGING DAYLIGHT

Compliance Requirements

Mandatory automatic daylighting controls are required in spaces that have 24 ft^2 or more of glazing and 120 W or more of general illumination in the combined primary sidelit and skylit zones. Not all buildings will realize the maximum benefit from adding daylighting controls because of the building's position or outside obstructions. Not all measures are required for all projects and there are many exceptions. Review **Section 130.1(d), Sections 141.0(b)2I - K** with **Table 141.0-E** to determine what each project mandates. The Energy Standards consider controlled luminaires as providing general illumination and not accent or task lighting.

Recommendations

Daylighting in commercial buildings can reduce electricity use for lighting by up to 50 percent or more, but also presents complex challenges. The IES' Recommended Practice for Daylighting Buildings (RP-5-13) provides up-to-date technological solutions and data for addressing the challenges of daylighting while maximizing its benefits. The RP-5-13, which is the authoritative reference guide for architects, engineers and lighting designers, includes information on daylight design techniques, delivery methods, glazing systems, shading techniques, control strategies, and daylight performance simulation tools. More at: **cltc.ucdavis.edu/publication/ies-rp-5-13-recommended-practice-daylighting-buildings**


PHOTO: STEELCASE

TASK LIGHTING FOR PERSONAL CONTROL

Compliance Requirements

Task lighting can play a critical role to meet or exceed the allowed LPD. With a thorough design using LED luminaires, 0.5W/ft^2 is achievable with current products at a reasonable cost.

In the Energy Standards, installing occupancy controls in large open office zones qualifies for a power adjustment factor. By utilizing power adjustment factors to apply control credits, this strategy can result in a lower claimed LPD when calculating for actual lighting power.

In office space projects that trigger the plug load control requirements in **Section 130.5**, energize task lighting from occupancy controlled outlets. Connect task lighting into networked controls to analyze energy use and occupancy patterns for maximum benefit.

Recommendations

Occupants have varying lighting requirements. Different visual tasks demand variations in lighting to produce ideal lighting conditions. Computer monitors require diffuse, ambient light with low screen glare effects. Printed materials require more light directed to a specific task plane (typically a desk surface) to avoid eye fatigue caused by low light levels. These task requirements drive target illuminance levels. Personally controlled task lighting helps to meet visual task requirements and should be included in the lighting design.

LARGE RETAIL & OUTLET STORES

Compliance in Practice

Switch Placement
Section 130.1(a)

In most areas, luminaires and manual ON/OFF controls are required to be located in close proximity. This may work well in office applications, but in retail settings unauthorized persons should not have access to the lighting controls. In malls, and retail and wholesale sales floors, the lighting control is required to be located so that a person using the lighting control can see the lights or area controlled by that lighting control. The switch does not have to be in that immediate vicinity and accessible to the public. Alternatively, it is permitted to use a lighting controls system where that area of the store is annunciated through the control interface, and the person controlling the lighting can see the effect of their actions remotely.

Floor, Wall and Window Displays
Section 130.1(a)

Floor, wall, and window displays are required to be switched separately. In the example on the next page, a separate switch in view of the window display lighting controls the window displays at the front of the store. Case display, ornamental and special effects lighting are also required to be switched separately. Controlled layers of lighting should be on circuits of 20 amps or less.

Track Lighting
Section 130.0(c)

Line-voltage track lighting is popular in retail because it can be adjusted to suit changing displays and focus attention on a small area. Line-voltage track heads compatible with screw-base lamps may not be counted at the wattage actually used by the lamp, even if highly efficacious LED lamps are used. Instead, use **Section 130.0(c)7** to determine how much to count towards the actual lighting power budget.

Additional Lighting Power Allowances

In areas approved to use the Tailored Method of the Prescriptive Approach, displays with very valuable merchandise may be eligible for additional lighting power. Under tailored method, additional lighting power also includes wall display, floor display, and ornamental lighting.

★Recommendations

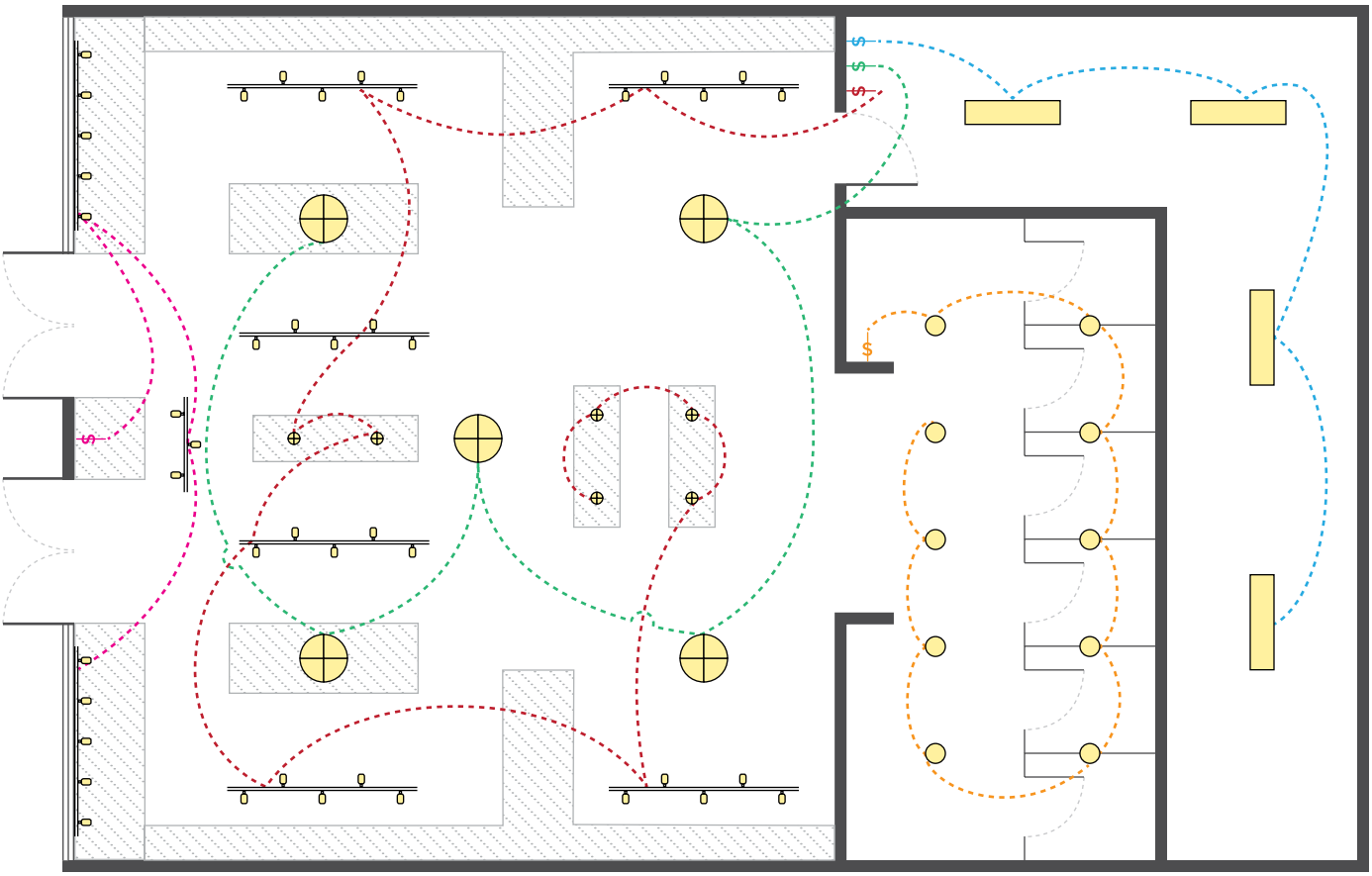
Flattering Fitting Rooms

High-CRI luminaires enhance the colors and textures of merchandise. Choose luminaires that provide soft, even distribution and consider lighting mirrors along either vertical edge to prevent unflattering shadows. In small fitting rooms, cove lighting located behind mirrors can help make these spaces feel larger.

Large Retail Store Lighting Schedule

Symbol	Luminaire Type	Lamp	Qty.	Watts	Total Watts	Efficacy (lm / W)
	Pendant	Induction	5	55	275	65
	Decorative pendant	Dedicated LED	6	10	60	60
	6" recessed downlight	Dedicated LED	10	12	120	67
	1 x 4 ceiling-mounted troffer	Dedicated LED	4	38	152	105
TRACK LIGHTING: The track lighting wattage claimed for compliance purposes used the method described in Section 130.0(c) 7 B iii, or 12.5 watts per linear foot of track lighting. All tracks have an integral current limiter that is certified to the Energy Commission.						
	8' track with 5 heads	LED track heads	8	100	800	47
	4' track with 3 heads	LED track heads	1	50	50	47

CONTROLS $ Switch **INSTALLED WATTS TOTAL** **1,467 W**



BOUTIQUES & SMALLER STORES

Compliance in Practice

Occupancy Controls

Section 130.1(c)

Placing occupancy sensors in stock rooms complies with the Energy Standards for lighting controls in secondary spaces. Occupancy sensors will also turn lights ON and OFF automatically for employees.

Recommendations

Accent Lighting

Use accent lighting strategically to draw customers' attention to certain displays and enhance merchandise details.

Ambient / Display Lighting Contrast

Keeping lower ambient light levels heightens the impact of display lighting and accent lighting in boutiques. This high-contrast lighting design strategy conveys a more upscale atmosphere to customers and saves energy.

Color Shifting Display Lighting

Consider tunable lighting to enhance displays and command customers' attention. Color-tunable LED lighting is one effective option.

Window Displays

Window displays are critical for attracting customers. Position lights to avoid glare in spaces with large front-facing windows.

Boutique Lighting Schedule

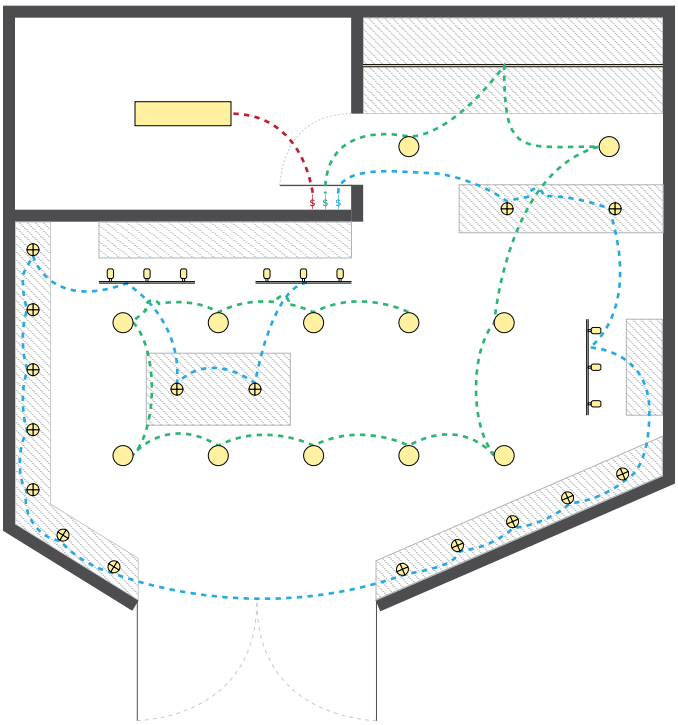
Symbol	Luminaire Type	Lamp	Qty.	Watts	Total Watts	Efficacy (lm / W)
◯	**6" recessed downlight**	Dedicated LED	12	9.5	114	67
⊕	**4" adjustable recessed downlight**	Dedicated LED	16	11	176	54.5
▭	**48" cove lighting**	Dedicated LED	3	14	42	98
▭	**1 x 4 ceiling-mounted troffer**	Dedicated LED	1	38	38	105
TRACK LIGHTING: The track lighting wattage claimed for compliance purposes used the method described in Section 130.0(c) 7 B iii, or 12.5 watts per linear foot of track lighting. All tracks have an integral current limiter that is certified to the Energy Commission.						
⊓⊓⊓	**4' track with 3 heads**	LED track heads	3	50	150	47

CONTROLS $ Switch **INSTALLED WATTS TOTAL 550 W**

PHOTO: ACUITY BRANDS

Luminaires with Integrated Controls

Occupancy-based lighting controls can save significant amounts of energy in areas, such as stock rooms, 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.



CONVENIENCE STORES

Compliance in Practice

Daylight Controls

Section 130.1(d)

Front windows provide a large amount of daylight in convenience stores. Luminaires providing general illumination in the **primary sidelit zone** will require daylighting controls to reduce lighting power when daylight is present.

Recommendations

Reflective Surfaces

Adjust spotlights and general light sources near refrigerated cases and windows to minimize glare.

Refrigerated Cases

1. Illuminated appliances such as open cooler cases and freezer cases offer an excellent opportunity to elevate a project from standard practice to best practice for maximum long-term benefit. LEDs perform well in cool temperature applications such as refrigerated cases. They use less energy for lighting than traditional fluorescent systems. They also produce less heat, reducing cooling demand and energy use.
2. Consider adding occupancy controls to further reduce the lighting energy use when the area is vacant. LED cases with integrated controls brighten when occupants are detected. The energy reduction opportunity from this feature is significant, in addition to the reduced energy use and maintenance costs from switching to LED.
3. The Energy Standards include lighting control requirements for refrigerated display cases in **Section 120.6(b)3**, but occupancy controls are not mandatory for every application. In this section, retail food stores that must comply can use automatic time switch controls or occupancy controls.

Convenience Lighting Schedule

Symbol	Luminaire Type	Lamp	Qty.	Watts	Total Watts	Efficacy (lm / W)
▭	**2x4 recessed troffer**	Dedicated LED	12	38	456	125
TRACK LIGHTING: The track lighting wattage claimed for compliance purposes used the method described in Section 130.0(c) 7 B iii, or 12.5 watts per linear foot of track lighting. All tracks have an integral current limiter that is certified to the Energy Commission.						
⎓	**8' track with 5 heads**	LED track heads	2	100	200	47

CONTROLS $ Switch (P) Photosensor **INSTALLED WATTS TOTAL 656 W**

Applying Sidelit Daylit Zone Calculations

Use the floor plan below to calculate sidelit zones.

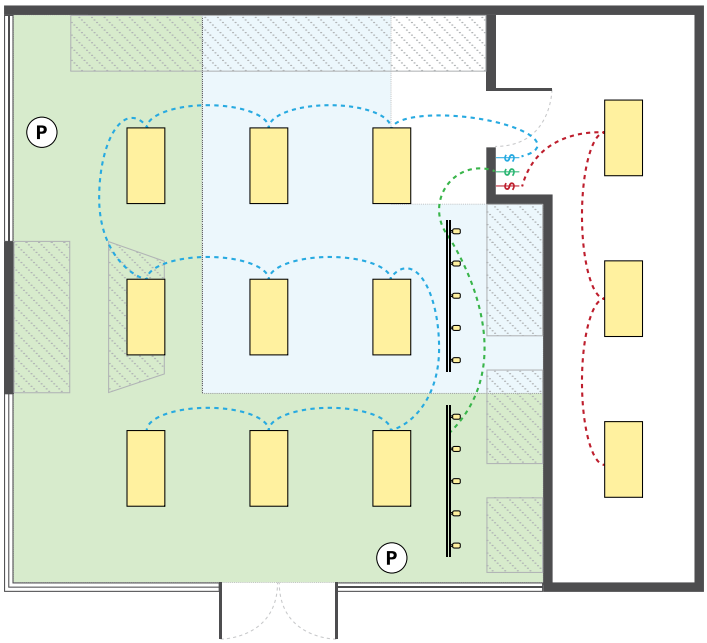
PRIMARY SIDELIT DAYLIT ZONE

1. Determine the window head height for each window. **The window head height is 10 ft.**
2. Determine the depth of the zone. **The depth of the zone is 10 ft, the window head height, into the area adjacent to the window.**
3. Determine the width of the zone. **The width of the zone is the window plus half the window head height (5 feet) on each side of the window.**

SECONDARY SIDELIT DAYLIT ZONE

1. Add one additional window head height to the same dimensions determined for the primary sidelit daylit zone.

The secondary sidelit daylit zone extends an additional 10 ft beyond the primary sidelit daylit zone adjacent to it.



COMMERICIAL RESTROOMS

Compliance in Practice

Manual Controls

Section 130.1(a)2

In public restrooms with two or more stalls, a manual switch may be used that is only accessible to authorized personnel. All other applicable lighting controls for the space are still required. Public restrooms can have at least one control step between 30-70 percent of full rated power rather than full multi-level controls.

Single-stall bathrooms less than 70 square feet can use countdown timer switches with max setting capability of ten minutes to comply with auto shut-off requirements.

Recommendations

Occupancy Sensors

Ultrasonic occupancy sensors can detect occupants through stall doors. This prevents lights from turning OFF while the space is in use. Ceiling-mounted dual-technology sensors that include both ultrasonic and passive infrared (PIR) technologies are available to assure the lighting stays on when customers need it.

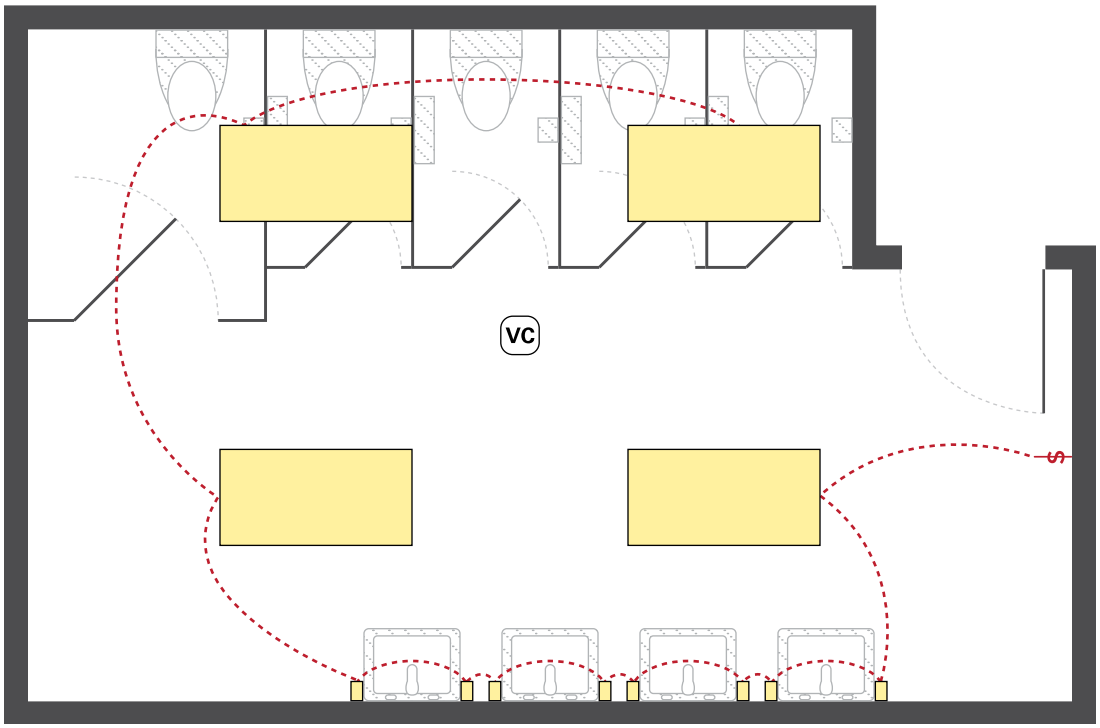
Vanity Lighting

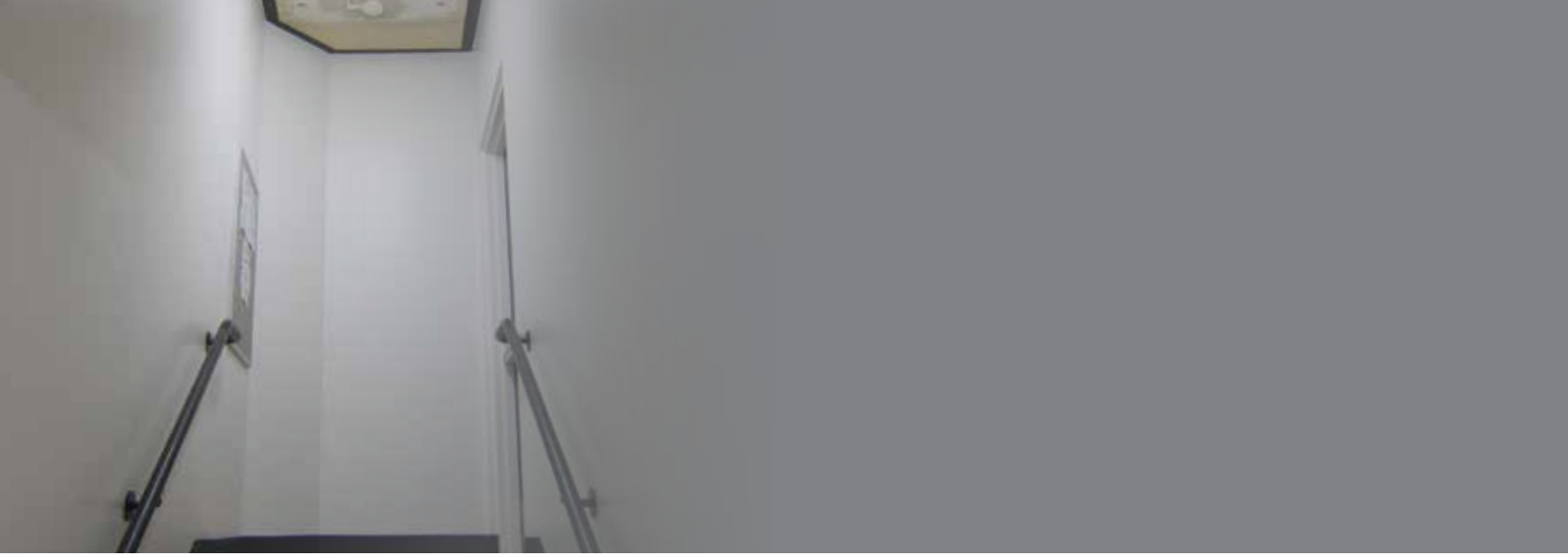
Flattering lighting around mirrors contributes to customers' overall retail experience. Vertical bath bars placed parallel to mirrors minimize unflattering shadows.

Commercial Restroom Lighting Schedule

Symbol	Luminaire Type	Lamp	Qty.	Watts	Total Watts	Efficacy (lm / W)
	2 x 4 recessed troffer	Dedicated LED	4	22	88	100
	3' vertical bath bar	Dedicated LED	8	15	120	60

CONTROLS $ Switch VC Vacancy Control **INSTALLED WATTS TOTAL** **208 W**





MAXIMIZE CONTROL IN TRANSITIONAL SPACES

Compliance in Practice

Lighting power for stairwell and corridors luminaires should be automatically reduced by at least 50 percent during vacant periods. Recommended light levels should be restored when occupants are detected from either direction. At 50 percent power, general lighting is often well above minimum levels required for egress lighting. After typical occupied hours, general lighting in stairwells and corridors should be shut off.

Recommendations

Retrofit Options: Bi-level luminaire retrofits are easy to implement and are designed to provide safe, reliable, and efficient lighting. If fluorescent luminaires are in good condition, a lamp-and-ballast retrofit with the addition of an external sensor technology will provide the bi-level functionality to meet the standards. These luminaires will also need to be shut off after occupied times per **Section 130.1(c)**.

LED Luminaires With Integrated Controls: There is an evolving product base of bi-level LED luminaires with integrated sensors made specifically for this application. Some have the ability to communicate between luminaires or back to a centralized system through a network. If luminaires are old and need replacing, the best long-term approach is installing new, dedicated LED strip luminaires with integrated dimming drivers. Installing new luminaires may be more cost-effective than retrofitting old luminaires.

Sensor Options: Ultrasonic sensors typically offer a better level of detection in constricted stairwell configurations compared to PIR sensors. PIR technology has proven effective when multiple sensors are integrated within the luminaire with different detection angles. In either case, make sure that the sensor technology is appropriately installed and commissioned for effective lighting control. An LED retrofit kit that supports bi-level functionality offers another option. Stairwells are often located at the perimeter of buildings where large windows may offer a significant opportunity for daylight harvesting. Photosensors need to be carefully placed in stairwells. 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 can be cost-effective in spaces that receive enough daylight. But like most lighting controls, they require careful installation and proper calibration to function properly.

EDUCATIONAL FACILITIES

Compliance in Practice

There are several specific requirements pertaining to classrooms. Classrooms must have partial on or vacancy sensor if also meeting **Section 130.1(b)**. Classrooms with a connected load of 0.7 W / ft^2 or less can have one control step between 30-70 percent instead of full multi-level control requirements.

Recommendations

ENERGY SAVINGS

Educational facilities often encompass many building occupancy types and end users. Traditional office spaces, classrooms, conference rooms and cafeterias are all typical occupancy types in an educational facility. For this reason, it is recommended that continuous dimming light sources be paired with dimmers, occupancy sensors and automatic daylighting as appropriate. It is also an ideal application for the use of spectrally tunable luminaires.

DIMMING DEVICES

It is critical to specify a dimmer that is compatible with the light source you are installing. This means checking the list of compatible dimmers for the light source when designing your new system.

OCCUPANCY SENSORS

The correct specification of the occupancy sensing technology is critical to the success of your lighting system. It is recommended that the use of the space be considered from a size and coverage pattern perspective as well as a mounting location perspective. Use of sound based technologies near air ducts will consistently result in false triggers and can turn your light system on during periods of vacancy.

AUTOMATIC DAYLIGHTING CONTROLS

Educational facilities often incorporate sidelit and skylit daylighting into the building's design. For this reason, it is important to deploy a fully-functional automatic daylighting control system so teachers and students alike can enjoy natural daylight conditions when it is available.

SPECTRAL TUNABLE LUMINAIRES

Spectrally tunable luminaires allow the user to specify the warmness or coolness of the light. For educational facilities, this feature is ideal for setting a mood or scene during periods of scheduled activities such as recess, study hall, or testing.

Lighting Schedule

Symbol	Luminaire Type	Lamp	Qty.	Watts	Total Watts	Efficacy (lm / W)
▭	**Linear pendant**	Dedicated LED	18	38	684	100

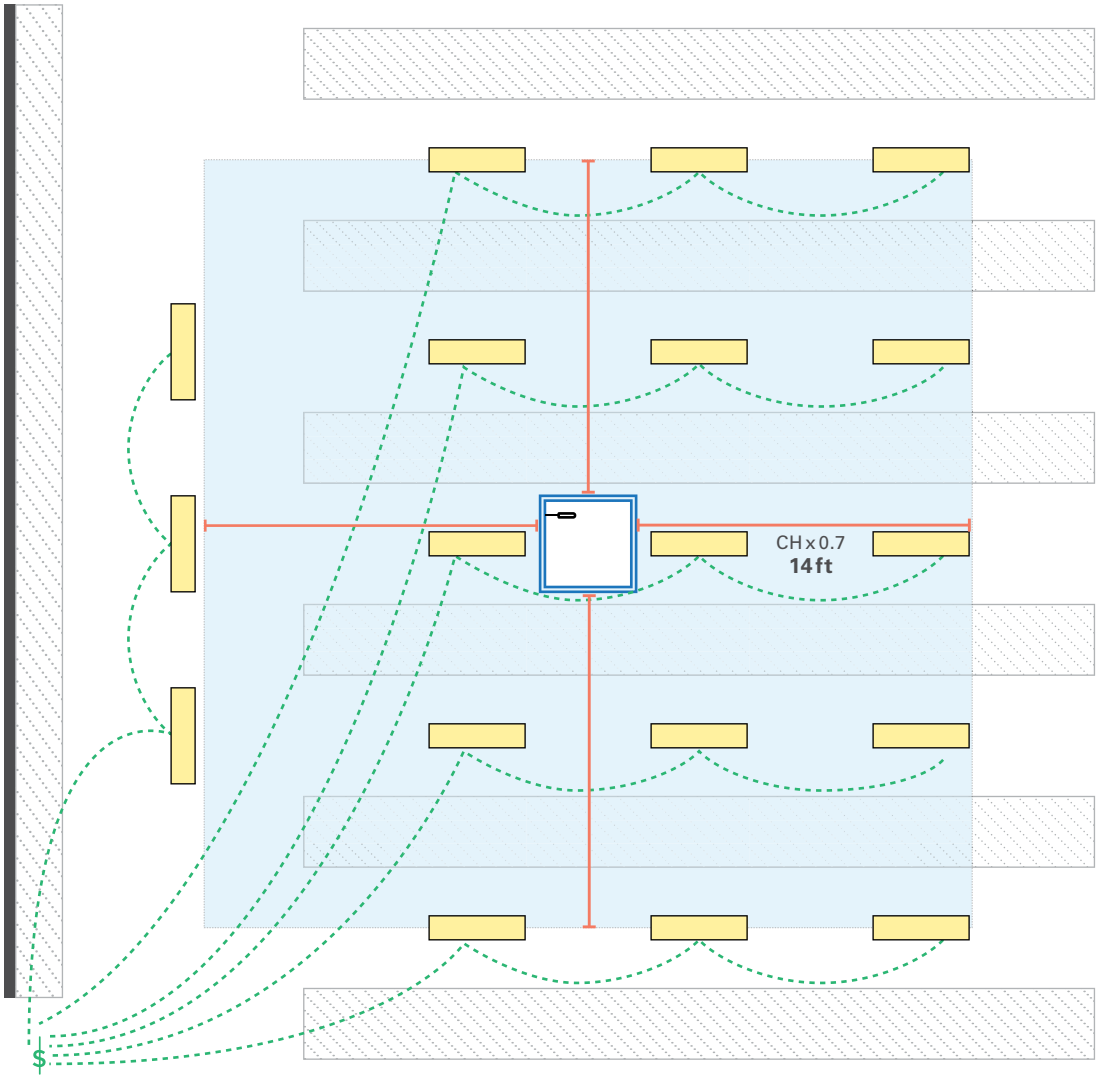
CONTROLS $ Switch ▬ Dual-loop photosensor

Applying Skylit Daylit Zone Calculations

The floor plan below has a square skylight 4' x 4', an average ceiling height of 20', and the desks are 2.5' tall.

SKYLIT ZONE

1. Define the shape of the skylight. **The square skylight will produce a square daylight zone.**
2. Determine the average ceiling height. **The average ceiling height is 20 ft.**
3. Multiply the CH by 0.7 and add the value in all directions around the skylight.
   The skylit zone is 14 ft in all directions. The skylit zone is 1,296 ft, centered on the skylight.




INNOVATION
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GLOSSARY

A

Accent lighting: Also called **display lighting**, this is directional lighting designed to provide additional lighting on display merchandise, in contrast with lower ambient, or general, light levels. It can be recessed, surface mounted or mounted to a pendant, stem or track.

Ambient lighting: Also known as **general lighting**, this lighting is designed to provide fairly uniform illumination throughout a space. Ambient lighting is generally supplemented by task lighting and accent lighting.

Astronomical time-switch control: An automatic lighting control device that switches lights ON or OFF at specified times of the day, or during astronomical events such as sunset and sunrise, to prevent energy waste when daylight is available. These devices can account for geographic location and calendar date. **Multi-level astronomical time-switch controls** reduce lighting power in multiple steps between full light output and their off setting.

B

Beam angle: Also known as **beam spread**, the width of the cone of light emitted from a light source, defined from the center of the beam to the angle where the intensity of light is half of its maximum. Narrow beam angles create a spotlight effect while broader beam angles spread light more evenly across a larger area.

C

Candela (cd): Unit of measurement for luminous intensity. One candela (cd) is equal to one lumen per steradian (lm/sr). A candle flame emits light with a luminous intensity of approximately one candela.

Case lighting Lighting designed for enclosed cases, such as glass display cases, that display jewelry, electronics or other valuable items.

Center beam candlepower (CBCP): Luminous intensity at the center of the beam from a reflector lamp, such as a parabolic aluminized reflector (PAR) lamp. CBCP is measured in candelas (cd).

Ceramic metal halide (CMH): A type of high-intensity discharge (HID) lamp commonly used in retail lighting, particularly high- and low-bay applications. Like **metal halide** lamps, CMH lamps generate light using a mixture of argon, mercury and metal halide vapors. CMH lamps are a newer variation of MH capable of producing white light with a CRI as high as 96. Full light output takes about 2–10 minutes, making them less compatible with adaptive lighting controls. They can produce energy savings of up to 90 percent when replacing incandescent sources.

Chandelier: A ceiling-mounted or suspended decorative luminaire that typically uses many small lamps and incorporates glass, crystal, ornamental metals, or other reflective decorative materials.

Correlated Color Temperature (CCT): Measured in Kelvins (K), CCT indicates the warmth or coolness of light emitted from a lamp. Low CCT indicates a warmer (more red) hue while high CCT denotes a cooler (more blue) appearance. Sources with a CCT of 2700–3000 K emit incandescent-like light while lamps with cooler color temperatures, such as 5000–6500 K, are often chosen to approximate bright daylight on a clear afternoon.

Color Rendering Index (CRI): The current industry-standard scale used to measure how truly light sources can render the colors of the objects they illuminate. The maximum CRI value is 100. Lamps with a high CRI (at least 80) render colors more accurately.

Compact fluorescent lamp (CFL): A type of fluorescent lamp shorter than 9 inches in overall length with a T5 glass tube (or smaller diameter) folded, bent or bridged to create a compact shape.

Countdown timer switch: A device featuring one or more preset countdown time periods that turns lighting (or other loads) ON when activated and automatically switches OFF when the selected time period elapsed.

D

Daylight control: An automatic lighting control device that uses one or more photosensors to detect changes in daylight contribution and automatically adjust electric lighting levels accordingly. A **multi-level daylight control** adjusts the luminous flux of the electric lighting system in either a series of steps or by continuous dimming in response to available daylight.

Daylit Zone: The floor area under skylights or next to windows. Title 24 includes building and lighting control requirements for specific types of daylit zones, including Primary Sidelit, Secondary Sidelit, and Skylit zones.

Decorative Lighting: Luminaires installed only for aesthetic purposes that do not serve as general, display or task lighting.

Dimmer: A lighting control device that adjusts the light output (or luminous flux) of an electric lighting system by decreasing or increasing the power delivered to that system. **Step Dimmers** provide end-users with one or more distinct light level settings (or steps) between maximum light output and off. **Continuous Dimmers** offer finer, more subtle control over a continuous range between maximum light output and the off setting.

E

Efficacy: The amount of light produced by a lamp or luminaire relative to the amount of electrical power it consumes (lm/W). To calculate lamp efficacy, divide the lamp's rated initial lumens (lm) by the rated lamp power (watts) without including auxiliaries such as ballasts, transformers and power supplies.

Energy Management Control System (EMCS): A computerized control system designed to regulate energy consumption by controlling the operation of one or more building systems, such as lighting and HVAC. An EMCS can also monitor environmental and system loads, adjust system operations, optimize energy usage, and respond to demand response signals.

F

Fluorescent: A low-pressure mercury electric-discharge lamp in which a phosphor coating transforms some of the ultraviolet energy generated into visible light.

G

General lighting See **ambient lighting**.

GU24: A bi-pin (versus screw-base) lamp holder and socket configuration based on a coding system by the International Energy Consortium, where "G" stands for the broad type of two or more projecting contacts, "U" distinguishes between lamp and holder designs of similar but not interchangeable types, and "24" indicates 24 millimeters center-to-center spacing between the electrical contact posts or pins.

H

HID lamps: High-intensity discharge (HID) lamps, such as metal halide or high-pressure sodium, lamps.

I

Illuminance: A measure of the intensity of incident light illuminating a surface; measured in lux (lx) or lumens (lm) per unit of surface area (lm/ft^2 or lm/m^2, for example).

Illumination: Density of light incident at a point on a surface, measured in footcandles (fc), perpendicular to the surface.

Incandescent: A type of lamp with a filament that gives off light when heated by an electric current.

L

Lamp: An electric light source, such as a light bulb or fluorescent tube. This is the term used in the lighting industry to describe replacement bulbs or tubes consisting of an electric light source, a holder and a cover.

Lighting control system: Technology consisting of two or more components and capable of providing full functionality for lighting control compliance.

Luminaire: Also commonly referred to as a **light fixture**, this is the lighting industry term for a complete lighting unit. It consists of a housing, socket, one or more lamps, a base that connects the fixture to a power source, and any integrated lighting control elements.

Light-emitting diode (LED): A solid-state diode that is constructed to emit colored or white light. LED is often used to describe a component, device or package that incorporates an array of light emitting diodes.

LED lamp: An LED component, device, or package, and other optical, thermal, mechanical, and electrical (control circuitry) components with an integrated LED driver (power source) and a standardized base that is designed to connect to the branch circuit via a standardized base, lamp holder or socket.

LED luminaire: A complete LED lighting unit consisting of a light source, driver and other parts designed to distribute light, to position and protect the light source, and to connect the light source to a branch circuit. The light source itself may be an LED component, package, device, array, module, source system, or lamp. The LED luminaire is intended to be connected directly to a branch circuit.

Lumen: The unit of measurement that describes the amount of light emitted from a light source. Higher lumen output indicates a brighter light source.

Luminaire: A complete lighting unit consisting of lamp(s) and the parts that distribute light, position and protect the lamp(s), and connect the lamp(s) to the power supply.

Luminance (L): The intensity of light reflected from a surface in a given direction. Measured in candelas per area unit (generally, cd/ft^2 or cd/m^2).

Luminous flux: The rate at which a light source emits visible light. This "flow rate" of light is measured as lumens over time and defines "light," generally, for purposes of lighting design and illuminating engineering.

M

Mandatory measures checklist: A form used by the building plan checker and field inspector to verify a building's compliance with the prescribed list of mandatory features, equipment efficiencies and product certification requirements. The documentation author indicates compliance by initialing, checking or marking N/A (for not applicable) in the boxes or spaces provided for the designer.

Metal halide (MH): A high-intensity discharge (HID) light source commonly used in retail, industrial and outdoor applications. MH lamps use a mixture of argon, mercury and metal halide. A hard outer glass covering absorbs much of the UV radiation emitted by MH lamps, thereby reducing their efficacy. MH lamps have CRI ratings of 60. Full light output takes about 2–10 minutes, making them less compatible with adaptive lighting controls. MH lamps produce more light than mercury vapor lamps and provide better color rendering, with CRI ratings of 60–96.

Motion sensor: A device that automatically turns lights OFF soon after an area is vacated. Motion sensor applies to outdoor lighting controls. When the device is used to control indoor lighting systems, it is called an occupant sensor, occupancy sensor, occupant-sensing device, or vacancy sensor.

Multi-level lighting control: A lighting control device that reduces power going to a lighting system, and the consequent light output of the system, in multiple discrete steps.

Multi-scene lighting control: In addition to all-OFF, this feature allows end-users to program or select pre-defined lighting settings for two or more groups of luminaires for multiple activities or displays within a space.

O

Occupant sensor: A device that automatically turns lights OFF soon after an area is vacated. The term occupant sensor applies to a device that controls indoor lighting systems. It is called a motion sensor when used to control outdoor lighting systems.

P

Pendant: A type of ceiling-mounted luminaire that is suspended from the ceiling, often above task surfaces.

Permanently installed lighting: All luminaires attached to the inside or outside of a building site, including: track and flexible lighting systems; lighting attached to walls, ceilings, or columns; inside or outside of permanently installed cabinets; internally illuminated case work; lighting mounted on poles, in trees, or in the ground; and lighting attached to ceiling fans and integral to exhaust fans other than exhaust hoods for cooking equipment. Portable lighting and lighting installed in appliances by the manufacturer is not considered permanently installed lighting.

Photocontrol: An electrical device that detects changes in illumination levels and controls lighting load at predetermined illumination levels. Automatically turns luminaires ON at dusk and turns OFF at dawn.

Pin-base luminaire: A luminaire, or fixture, that accepts lamps with a pin base, as opposed to a screw base. GU-24 pin-base luminaires prevent the use of low-efficacy lamps in high-efficacy luminaires.

Portable lighting: Lighting with plug-in connections for electric power, including: table lamps and freestanding floor lamps, lighting attached to modular furniture, workstation task lights, lights attached to workstation panels, movable displays, and other equipment that is not **permanently installed lighting.**

R

Readily accessible: Capable of being reached quickly for operation, repair or inspection. Readily accessible items must be accessible without the use of special equipment, removal of obstacles or need for climbing.

S

Screw-base luminaire: A luminaire, or fixture, with a socket that accepts screw-base lamps (e.g., incandescent, CFL or LED replacement lamps). Screw-base luminaires are considered low-efficacy under Title 24, Part 6 because they are compatible with low-efficacy lamps.

Skylight: A window (fenestration surface) installed in a roof and having a slope of less than 60 degrees from the horizontal plane.

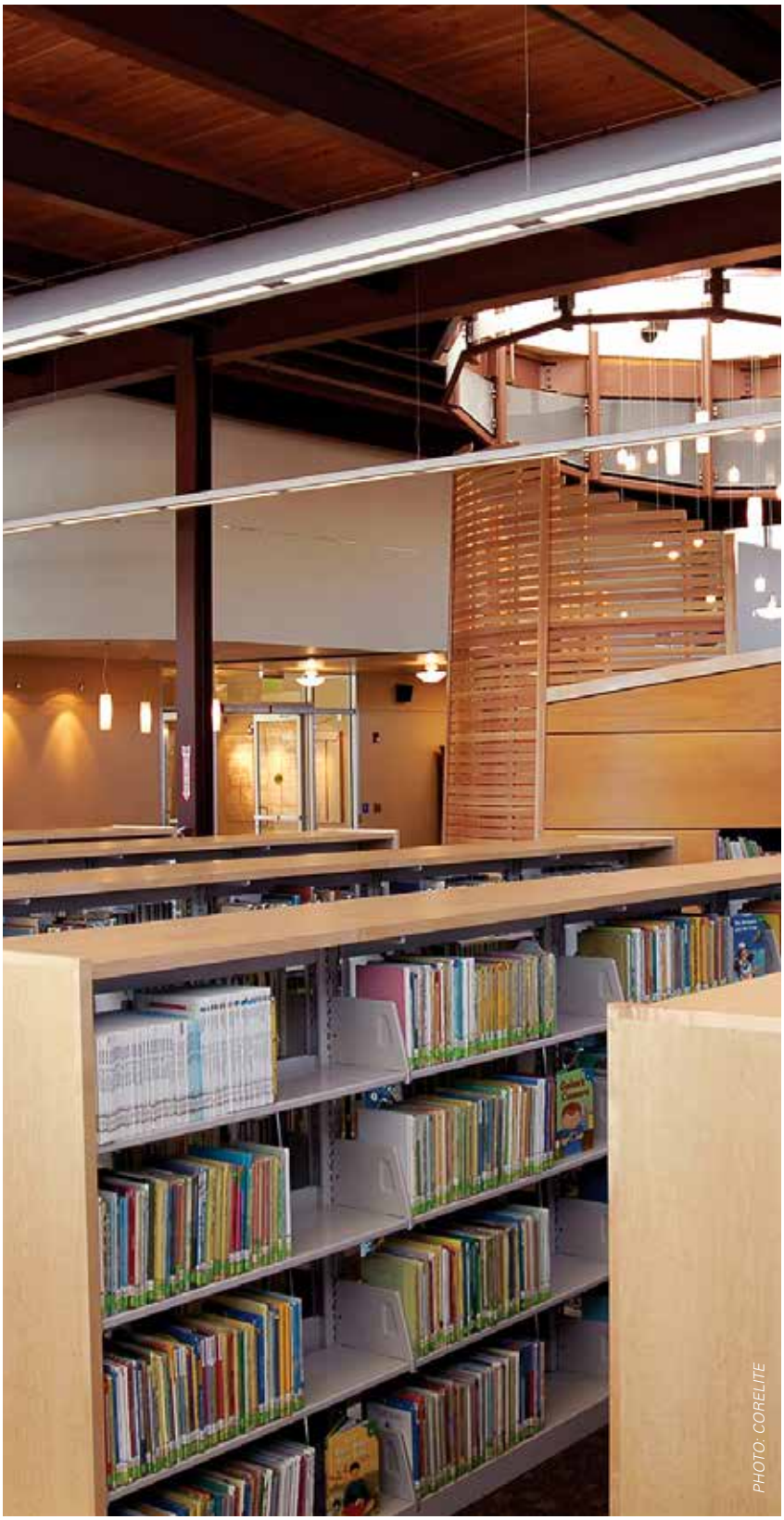

PHOTO: CORELITE

T

Task lighting: Lighting that is designed to meet the specific illumination needs of an area designated for specific tasks.

Time switch: Also called a **timer switch** or **timer**, this device is designed to automatically control lighting based on time of day.

Track lighting: A system that utilizes luminaires mounted to a track, rails or cables.

U

Utility room: A non-habitable room or building (not a bathroom, closet, garage, or laundry room) that contains only HVAC, plumbing or electrical controls, or equipment.

V

Vacancy sensor: An occupant sensor that requires occupants turn lights on manually but automatically switches lights off soon after an area is vacated. Also called a **manual-ON occupant sensor** or **manual-ON / automatic-OFF sensor**.

W

Watt: The unit of measure for the electric power used by a lamp or luminaire.

APPENDIX

TABLES

The original versions of the tables in this section can be found in the 2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings. These tables are used for determining compliance what is required for compliance with Title 24, Part 6 and in the process of calculating lighting energy budgets.

Table 140.6-B: Complete Building Method Lighting Power Density Values (W/ft^2)

Type of Use	Allowed Lighting Power
Auditorium Building	1.4
Classroom Building	1.1
Commercial and Industrial Storage Buildings	0.6
Convention Center Building	1.0
Financial Institution Building	1.0
General Commercial Building / Industrial Work Building	1.0
Grocery Store Building	1.5
Library Building	1.2
Medical Buildings / Clinic Building	1.0
Office Building	0.8
Parking Garage Building	0.2
Religious Facility Building	1.5
Restaurant Building	1.1
School Building	0.95
Theater Building	1.3
All Other Buildings	0.5

Table 140.6-C: Area Category Method Lighting Power Density Values (W/ft²)

Primary Function Area	Allowed Lighting Power (W/ft²)	Primary Function Area		Allowed Lighting Power (W/ft²)
Auditorium Area	1.4[3]	Library Area	Reading Areas	1.1[3]
Auto Repair Area	0.9[2]		Stack Areas	1.5[3]
Beauty Salon Area	1.7	Lobby Area	Hotel lobby	.95[3]
Civic Meeting Place Area	1.3[3]		Main entry lobby	.95[3]
Classroom, Lecture, Training, Vocational Areas	1.2[5]	Locker/ Dressing Room		0.7
Commercial and Industrial Storage Areas (conditioned and unconditioned)	0.6	Lounge Area		.9[3]
Commercial and Industrial Storage Areas (refrigerated)	0.7	Malls and Atria		.95[3]
Convention, Conference, Multipurpose and Meeting Center Areas	1.2[3]	Medical and Clinical Care Area		1.2
Corridor, Restroom, Stair, and Support Areas	0.6	Office Area	>250 square feet	0.75
Dining Area	1.0[3]		≤ 250 square feet	1.0
Electrical, Mechanical, Telephone Rooms	0.55[2]	Parking Garage Area	Parking Area[10]	0.14
Exercise-Center, Gymnasium Areas	1.0		Dedicated Ramps	0.3
Exhibit, Museum Areas	1.8		Daylight Adaptation Zones[9]	0.6

Table 140.6-C (continued)

Primary Function Area		Allowed Lighting Power (W/ft²)	Primary Function Area		Allowed Lighting Power (W/ft²)
Financial Transaction Area		1.0[3]	Religious Worship Area		1.5[3]
General Commercial and Industrial Areas	Low bay	0.9[2]	Retail Merchandise Sales, Wholesale Showroom Areas		1.2[6 and 7]
	High bay	1.0[2]	Theatre Area	Motion Picture	0.9[3]
	Precision	1.2[4]		Performance	1.4[3]
Grocery Sales Area		1.2[6 and 7]	Transportation Function Area	Concourse & Baggage	0.5
				Ticketing	1.0
Hotel Function Area		1.4[3]	Video Conferencing Studio		1.2[8]
Kitchen, Food Preparation Areas		1.2	Waiting Area		0.8[3]
Laboratory Area, Scientific		1.4[1]	All other areas		0.5
Laundry Area		0.7			

Footnotes for Table 140.6-C:

See Section 140.6(c)2 for an explanation of additional lighting power available for specialized task work, ornamental, precision, accent, display, decorative, and white boards and chalk boards, in accordance with the footnotes in this table. The smallest of the added lighting power listed in each footnote below, or the actual design wattage, may be added to the allowed lighting power only when using the Area Category Method of compliance.

Footnote number	Type of lighting system allowed	Maximum allowed added lighting power (W/ft² of task area unless otherwise noted)
1	Specialized task work	0.2 W/ft²
2	Specialized task work	0.5 W/ft²
3	Ornamental lighting as defined in Section 100.1 and in accordance with Section 140.6(c)2	0.5 W/ft²
4	Precision commercial and industrial work	1.0 W/ft²
5	Per linear foot of white board or chalk board	5.5 W per linear foot
6	Accent, display and feature lighting—luminaires shall be adjustable or directional	0.3 W/ft²
7	Decorative lighting—primary function shall be decorative and shall be in addition to general illumination	0.2 W/ft²
8	Additional Videoconferencing Studio lighting complying with all of the requirements in Section 140.6(c)2Gvii.	1.5 W/ft²
9	Daylight Adaptation Zones shall be no longer than 66 feet from the entrance to the parking garage	
10	Additional allowance for ATM locations in parking garages	200 Watts for first ATM location
	Allowance per ATM	50 Watts for each additional ATM location in a group

Table 140.6-D: Tailored Method Lighting Power Allowances

Primary Function Area	General Illumination Level (Lux)	Wall Display Power (W/ft)	Allowed Combined Floor Display Power and Task Lighting Power (W / FT²)	Allowed Ornamental/ Special Effect Lighting
Auditorium Area	300	2.25	0.3	0.5
Civic Meeting Place	300	3.15	0.2	0.5
Convention, Conference, Multipurpose, and Meeting Center Areas	300	2.50	0.4	0.5
Dining Areas	200	1.50	0.6	0.5
Exhibit, Museum Areas	150	15.0	1.2	0.5
Financial Transaction Area	300	3.15	0.2	0.5
Grocery Store Area	500	8.00	0.9	0.5
Hotel Function Area	400	2.25	0.2	0.5
Lobby Area				
Hotel Lobby	200	3.15	0.2	0.5
Main Entry Lobby	200	0	0.2	0
Lounge Area	200	7.00	0	0.5
Malls and Atria	300	3.50	0.5	0.5
Religious Worship Area	300	1.50	0.5	0.5
Retail Merchandise Sales, and Showroom Area	400	14.00	1.0	0.5
Theater Area				
Motion picture	200	3.00	0	0.5
Performance	200	6.00	0	0.5
Transportation Function Area	300	3.15	0.3	0.5
Waiting Area	300	3.15	0.2	0.5

Table 140.6-E: Adjustments for Mounting Height Above Floor

Height in feet above finished floor and bottom of luminaire(s)	Floor Display or Wall Display — Multiply by
< 12'	1.00
12' to 16'	.87
> 16'	.77

Table 140.6-F: Room Cavity Ratio (RCR) Equations

Determine the Room Cavity Ratio using one of the following equations

Room cavity ratio for rectangular rooms

$$RCR = \frac{5 \times H \times (L + W)}{L \times W}$$

Room cavity ratio for irregularly shaped rooms

$$RCR = \frac{2.5 \times H \times P}{A}$$

H =Vertical distance from the work plane to the center line of the lighting fixture
L = Length W = Width P = Perimeter A = Area of the room

Table 140.6-G: Illuminance Level (Lux) Power Density Values (W/ft²)

Illuminance Level (lux)	RCR ≤2.0	RCR >2.0 and ≤3.5	RCR >3.5 and ≤7.0	RCR >7.0
50	0.18	0.22	0.32	0.46
100	0.3	0.38	0.56	0.84
200	0.48	0.64	0.88	1.34
300	0.64	0.82	1.12	1.76
400	0.78	0.98	1.34	2.08
500	0.9	1.10	1.52	2.32
600	1.06	1.26	1.74	2.6
700	1.24	1.46	1.82	2.96
800	1.44	1.7	2.28	3.30
900	1.66	2.0	2.64	3.74
1,000	1.84	2.2	2.90	4.06

APPENDIX

RESOURCES


PHOTO: FINELITE

COMPLIANCE RESOURCES

2016 Title 24 Building Energy Efficiency Standards and Related Documents

energy.ca.gov/title24/2016standards

Visit the Energy Commission website to download the 2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings. The nonresidential standards should be the first resource for any contractor, builder or designer with questions about Title 24 regulations. Supporting documents and information on how to obtain public domain software for complying with the 2016 Energy Standards are also available. The 2016 Nonresidential Compliance Manual and 2016 Nonresidential Alternative Calculation Method Reference Manual are among the related documents available.

Energy Standards Hotline

Toll-free in California: (800) 772-3300

Title24@energy.ca.gov

The Energy Standards Hotline is a resource for any questions regarding the Energy Standards. The hotline is available Monday through Friday, 8 a.m–12 p.m. and 1–4:30 p.m.

California Energy Commission Modernized Appliance Efficiency Database System

cacertappliances.energy.ca.gov/Login.aspx

This online database features Quick Search and Advanced Search options that allow users to easily verify if lighting products have been certified to the Energy Commission as meeting applicable efficiency standards.

Title 20 Appliance Efficiency Regulations

energy.ca.gov/appliances

Energy efficiency and performance standards for appliances, including ballasts, lamps, luminaires, and lighting controls, are detailed in the 2016 Appliance Efficiency Regulations. This and other resources are available through the Energy Commission's website.

Energy Code Ace

energycodeace.com

This new site developed by the California Statewide Codes & Standards Program provides free tools, trainings and resources to help users meet the latest Title 24, Part 6 requirements. Visitors can download fact sheets, trigger sheets, checklists, and information on classes (online or in person) and workshops.

California Advanced Lighting Controls Training Program (CALCTP)

calctp.org

CALCTP educates, trains, and certifies licensed electrical contractors and state certified general electricians in the proper installation, programming, testing, commissioning, and maintenance of advanced lighting control systems.

California Lighting Technology Center

cltc.ucdavis.edu/title24

CLTC was established through joint efforts by the Energy Commission and the University of California, Davis. CLTC develops and tests state-of-the-art, energy-saving lighting and daylighting innovations. CLTC also offers training and educational programs on energy-efficient lighting.

DesignLights Consortium Qualified Products List
designlights.org/qpl

This online database of quality, high-efficiency LED products for the commercial sector is maintained by the DesignLights Consortium, a project of the regional non-profit, Northeast Energy Efficiency Partnerships. It allows users to search for LED products by criteria (such as CRI and light output), categories (including display case lighting and track lighting), manufacturer, or keyword. Products listed may or may not qualify for certification to the Energy Commission.

National Lighting Contractors Association of America (NLCAA)
nlcaa.org

NLCAA, Inc. is a non-profit organization approved by the California Energy Commission to implement the training and certification of Acceptance Test Technicians in order to serve a critically important function for ensuring high quality installation of energy efficiency lighting controls systems in California non-residential lighting.

CLASSES

California Association of Building Energy Consultants' Title 24 Resources
cabec.org/title24info.php

California Training Schedule for Building Operator Certification
theboc.info/ca/ca-schedule.html

Education Schedule for the Building Owners and Managers Association
boma.org/TrainingAndEducation/Pages/default.aspx

Workshop & Event Calendar for the Center for Sustainable Energy, California
energycenter.org/events

UTILITY EDUCATION & DEMONSTRATION CENTERS

All or most of these California utility centers host Title 24 lighting classes. They also house lighting technology demonstration spaces and tool lending libraries that can provide visitors with energy and light meters, data loggers, lighting design software, lighting design manuals, and other resources.

Online calendars list training events and workshops. Some websites offer virtual video tours of the demonstration centers and information on resources and services. Visitors and class participants can also learn about the utilities' rebate and incentive programs.

Pacific Gas and Electric Company (PG&E)
pge.com

Pacific Energy Center (PEC), San Francisco

Energy Training Center, Stockton

Sacramento Municipal Utility District
smud.org

Energy & Technology Center, Sacramento

San Diego Gas & Electric
sdge.com

Energy Innovation Center, San Diego

Southern California Edison (SCE)
sce.com

Energy Education Centers
Irwindale, Tulare and on-location in other cities

MANUFACTURER TRAINING CENTERS

Acuity Brands Center for Light&Space
Berkeley, CA
acuitybrands.com

Eaton's Cooper Lighting Business
Online Design Center
cooperindustries.com

Lutron
California Experience and Training Center
Irvine, CA
lutron.com

For more information and resources about Title 24, Part 6, visit the CLTC website at ***cltc.ucdavis.edu/title24****.*

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