The California State University

Office of the Chancellor

Outdoor Lighting Design Guide

Acknowledgement

The California State University (CSU) gratefully acknowledges the effort and work in the preparation of this document of the CSU Mechanical Review Board whose members are Jai Agaram, Douglas Effenberger, Paulo Fundament, Malcolm Lewis, Kent Peterson and Steven Taylor. Satinder Gulati, University Engineer at The CSU Office of the Chancellor contributed to and coordinated the effort. Comments or inquiries may be directed to:

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1.0 INTRODUCTION

The purpose of this Guide is to provide CSU campuses with guidelines for outdoor lighting design in order to provide a comfortable nighttime environment, maximize energy efficiency, and improve campus aesthetics. Issues related to public safety must also be considered, on a case-by-case basis, when applying the design techniques presented in this guideline.

This Guide covers:

- Lighting Design Goals
- Lighting Design Strategies to meet Design Goals
- Control Strategies and Methods
- Lamp Types Preferred for Energy and Maintenance Savings

2.0 LIGHTING DESIGN GOALS

2.1 Compliance with Applicable Codes

Outdoor lighting designs must comply with the following State of California Codes:

Refer to California Energy Code, (California Code of Regulations Title 24, Part 6) Section 147 for minimum requirements for outdoor lighting power allowances. Refer to Section 132 for luminaire cutoff requirements and lighting control requirements.

Refer to California Electrical Code (California Code of Regulations Title 24, Part 3) for electrical requirements for outdoor lighting, including circuiting, overcurrent protection, and grounding.

All electrical devices must be listed and labeled for their intended use. Outdoor electrical components such as luminaires and ballasts shall be listed for wet locations and environments by an agency such as Underwriters Laboratories (UL).

2.2 Good Nighttime Visibility

The primary purpose of the nighttime lighting system is to provide good nighttime visibility and a sense of security for the campus community and visitors. Good visibility does not necessarily mean high levels of light. Many visual issues must be addressed to meet this goal including light source color, reduction of glare, appropriate uniformity of illuminance, and vertical surface brightness. Addressing all of these issues creates a comfortable visual environment.

2.3 Low Maintenance

Luminaires and lamps should be selected based on long life and durability in order to reduce maintenance over the life of the equipment. The future cost of maintenance, such as re-lamping and replacement parts, can quickly overwhelm the initial cost of the lighting equipment. Luminaires should be designed to provide access to the lamp and ballast without the use of special tools in order to reduce the amount of time required to replace the lamp or ballast. The luminaires should also be selected and specified from nation-wide, established manufacturers that have a minimum of 15 years in the lighting industry. The luminaire manufacturers should have a distributor geographically close to the campus in order to reduce shipping and lead time for replacement parts.

2.4 Energy Efficiency

A goal for any campus should be to reduce energy consumption. The exterior lighting design can contribute to this goal in several ways – careful use of light to brighten surfaces and enhance visibility, the use of energy efficient, white light sources, and the incorporation of controls.

Lighting vertical surfaces not only enhances the campus architecture, but improves the overall nighttime visibility. It is an effective use of light rather than trying to cover an entire ground area to provide a high light level.

Our eyes' peripheral vision performs better under white light sources such as induction and fluorescent rather than orange light sources such as high pressure sodium. The result of this phenomenon is that less white light can be used to achieve good visibility. By using energy efficient sources such as induction, fluorescent, and LED, the most light can be produced with the least amount of electricity necessary. Lamps with a high *efficacy* should be selected. Efficacy is defined as the amount of light produced by a lamp, usually measured in lumens, divided by the amount of energy consumed to produce the light, usually measured in watts. The California Energy Code mandates a lamp efficacy of at least 60 lumens per watt for lamps rated over 100 watts.

Once the light is used effectively and produced efficiently, it can be controlled so that it is energized only when necessary. Controls may be a simple photocell or time switch that turns the luminaire on at dusk and then off at dawn. They can also be more complex and controlled as groups or monitored with a campus-wide energy management system. Refer to Section 4 of this guide for lighting control details.

2.5 Reduced Light Pollution

Light pollution or sky glow is caused by light aimed directly up into the sky and by light reflected off the ground or objects. Sky glow prevents the general public and astronomers from seeing the stars.

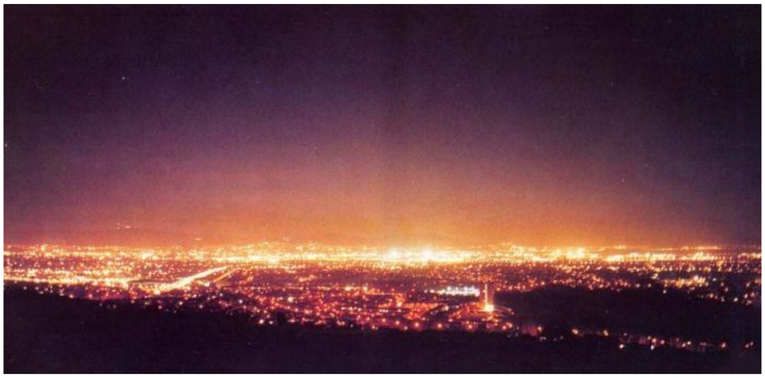


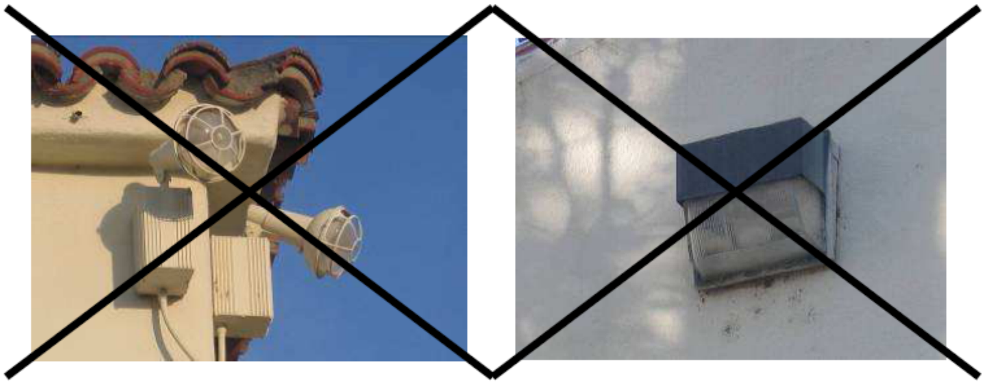
Photo of sky glow over Belfast. Photo by Peter Paice

Satellite image of light reflected into space. Photo by NASA

To minimize light pollution, use fully shielded luminaires or IESNA full cutoff type luminaires for area and roadway lighting. Full cutoff luminaires are designed with a shield to direct all light downward from the luminaire. The California Energy Code requires all luminaires over 175W to meet cutoff requirements. However, to achieve minimal light pollution, design guidelines and specifications should stipulate all luminaires as full cutoff type, regardless of wattage.

Image provided courtesy of Abacus Lighting

Floodlights, wall packs and other un-shielded luminaires are the major contributors to sky glow. Excess illumination, even with shielded luminaires, reflects unnecessary light back into the atmosphere and also adds to sky glow.



Less shielded luminaires may be used at low mounting heights if the lumen output of the lamp is limited to 3500 initial lamp lumens. These applications, such as pedestrian and entry lighting, typically require greater vertical illuminance for identification of features and landmarks. Where possible, the control of lighting with motion sensors energizes lighting only when needed, thus reducing light pollution.

Consult local codes regarding luminaire selection and cutoff requirements to avoid light pollution. Municipalities in the area of an observatory or military facility may have stricter requirements regarding light pollution allowances. Local codes or campus design guidelines may also specify a certain type of lamp (e.g. high pressure sodium) or lamp color temperature that is required for outdoor lighting.

2.6 Minimal Light Trespass

Light trespass is also referred to as nuisance glare. Uncontrolled light sources such as floodlights and unshielded wall pack luminaires mounted at a low elevation create glare and are often the cause of light trespass. Since glare inhibits our ability to “see” objects, features, and decreases contrast, all designs must minimize glare for good visibility.

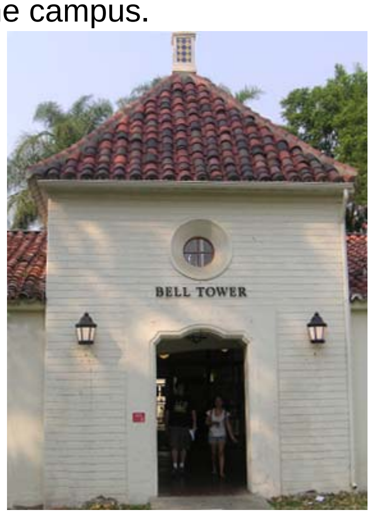
To minimize light trespass, use only fully shielded or IESNA full cutoff luminaires for area lighting. When unshielded luminaires such as decorative luminaires are used at low mounting heights, reduce the lamp brightness to that of a 3500 lumen output or less. Do not overlight areas because reflected light can also result in complaints and poor nighttime visibility from increased glare. Outdoor lighting that is reflected into natural areas can also affect wildlife in the natural area.

Locate luminaires to avoid any direct light into adjacent building windows, especially dorm rooms. Luminaires attached to exterior building façades should be located between windows, not directly above windows. Also, consider dimming or turning off lighting when not needed and activate with motion sensors or timers when activity occurs to minimize light trespass into building interiors.

2.7 Integrate with Campus Aesthetics

Not only must the lighting system perform well at night, but the selected aesthetic must complement the campus architecture and surroundings during the day. The lighting aesthetic should be consistent between similar areas across the campus.

Campus lighting standards should be developed for all applicable outdoor lighting applications, including building façades, pedestrian pathways, campus roads, parking lots, athletic fields, signs, and stairways. Selection of luminaires and lamps as a campus standard will help maintain a consistent aesthetic across the campus.



3.0 LIGHTING DESIGN STRATEGIES

3.1 Create Vertical Surface Brightness

The use of lighting for buildings and monuments as markers or reference points is important for visual orientation. Buildings and monuments, when properly illuminated, may act as visual anchors or serve as points of arrival for the campus. Surface brightness is critical for good nighttime visibility. Brightness of vertical surfaces especially improves visibility and a sense of security for pedestrians. With lighted backgrounds or walls, people can see the movement of others in silhouette. It also defines walls of an exterior space making the surroundings feel more comfortable visually as well as secure. The following renderings and photographs illustrate the concept of surface brightness as it could be applied to the campus:

Note that the actual light sources are concealed and provide uniform illumination to minimize glare while the illuminated surfaces create a soft and comfortable visual environment. Building entrances are illuminated with downlighting for wayfinding.

3.2 Enhance Wayfinding

Nighttime lighting can aid pedestrians in finding their way around campus. This may be straight-forward such as lighting directional or informational signs. It can also be more subtle such as brightening building entries or pathway intersections. Illuminated iconic facades can also orient people at night and provide additional wayfinding. By using consistent light levels and lighting equipment across the campus, a clear relationship is established between area types and lighting application for each area type.

3.3 Minimize Glare

Direct glare is caused by excessive light entering the eye from a bright light source. The potential for direct glare exists any time one can "see" a light source. With direct glare, the eye has a harder time seeing contrast and details. It also can make other surroundings seem darker. A lighting system designed solely on foot-candle lighting levels, tends to aim more light outwards and increases the potential for glare. Glare can also be minimized by appropriate shielding of luminaires. A fully shielded luminaire can use a lamp of a higher lumen output than an unshielded luminaire, while maintaining a visually comfortable level of glare.

To further minimize glare, all brightness levels in the nighttime environment should be in approximately the same range. For comparison, a full moon has a luminance level of about 2,500 cd/m^2, while an unshielded floodlight has a level of 22,000 cd/m^2. By illuminating building surfaces and shielding light sources, most of the luminance levels on the campus will be below the luminance of a full moon.

3.4 Maintain Lighting Uniformity

Lighting uniformity refers to the evenness of light along a surface area. Our eyes are continually adapting to the brightest object in our field of view. As areas become less uniform, details become harder to see. Uniformity is also related to glare. If the eye must adapt to a really bright light source, it will have a harder time seeing objects of lower brightness. This issue must be considered when designing lighting for roadways, pedestrian paths, and parking lots. With lighting that is not uniform, pedestrians may become invisible to oncoming motorists, because the vehicle driver's eyes have adapted to the bright source, and will not be able to identify the pedestrian if the pedestrian is in a dark area relative to the bright light source. Providing uniform lighting and minimizing glare will aid in pedestrian and vehicular safety.

In the photograph to the right, note how the pedestrian "disappears" in an environment without uniform lighting. There is only one lamp illuminating the roadway intersection and crosswalks. By using several luminaires to achieve more uniform lighting across the roadways, pedestrian visibility is greatly enhanced.

3.5 Provide Appropriate Light Levels

Light level or illuminance, measured in foot-candles, is a measure of light falling onto a surface. While this is not a value that we actually see, it is a basis for some lighting criteria. Policies at some campuses specify a minimum foot-candle value for outdoor areas, regardless of the lighting application. While adequate light levels need to be provided for good visibility, this criteria is not the only or most important lighting strategy. In fact, with good surface brightness, lighting uniformity, and good color rendition using white light sources from induction or metal halide lamps, light levels can be lower and provide equal or better visibility.

In the above photo, the left side of the room has higher foot-candle values, as measured on the floor, yet the right side of the room appears brighter. The ceiling on the right has been painted white, reflecting more light. The luminaires have been configured to provide a portion of uplighting to illuminate the ceiling. This strategy gives the appearance of a brighter environment, despite lower foot-candle values. Using vertical surface illumination and selection of luminaires that minimize glare can provide an environment that appears brighter, despite lower foot-candle values.

4.0 LIGHTING CONTROL STRATEGIES

4.1 Compliance with Applicable Codes for Lighting Control

The California Energy Code mandates all permanently installed outdoor lighting to be controlled by a photosensor or astronomical time switch to automatically turn off lighting when daylight is available. In addition, lighting of building facades, parking lots, garages, canopies must be controlled such that the power usage in watts can be reduced by 50-80 percent. This requirement can be accomplished by use of bi-level switching or continuous dimming through a range that includes 50 to 80 percent reduction in power consumption.

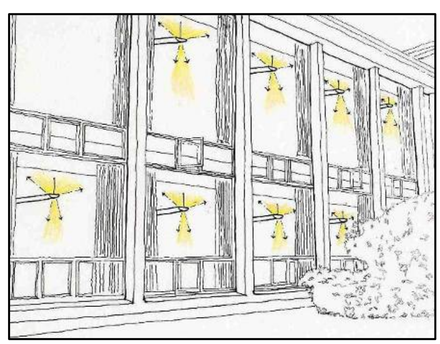
Judicious selection and installation of controllers such as time switches and photosensors can realize significant energy savings. Integration of exterior lighting circuits with an interior lighting controller or EMS system can result in greater savings.

4.2 Control Strategies

A. Reduction of Accent and Non-Essential Lighting Energy Use

During a typical night, students, staff, and faculty are traversing the campus from dusk to midnight. After midnight, the number of people moving about the campus is minimal. Superfluous lighting, such as feature, landscape, and art lighting, should be turned off from midnight to dawn. When controlled by a programmable time switch, this lighting can be configured to remain off completely during campus holidays. It is recommended to leave pathway and building façade lighting on throughout the night for security purposes, however, a time switch in combination with a motion sensor can realize energy savings during periods when the number of persons on the campus site is minimal.

B. Coordinate Indoor and Outdoor Lighting



Building interior lighting may contribute to light pollution and light trespass if not properly controlled and located. This may occur with bright decorative luminaires or indirect, pendant mounted lighting located next to large window walls. During design or retrofit of a building, the locations and positions of interior lighting should be considered along with locations of exterior lighting. Avoid placing large interior lights next to windows, in order to minimize light trespass.

Interior lighting, regardless of type, can cause light trespass and a significant increase in energy use if the lights remain on throughout the night. It is recommended to control both interior and exterior lighting from the same controller. The controller can then be programmed to control lighting with a nighttime scheme that keeps only minimal interior lighting energized.

In the above illustration, note that the exterior lighting turns on while the interior lighting remains on. There is no control coordination between interior and exterior lighting, resulting in excessive use of lighting and energy usage.

In the above illustration, the interior lighting is turned off, while the exterior lighting is carefully controlled to provide adequate illumination. Motion sensors for both interior and exterior lighting can turn off lighting when the building is not in use, but turn the lighting back on for periods of activity. Coordination of interior and exterior lighting control can provide significant energy savings per building.

C. Monitor Performance of Controller

Controllers must be periodically inspected and monitored to ensure proper operation, and continued energy savings. A stuck contactor, miss-aligned photosensor, or improperly programmed time switch can cause exterior lighting to remain on during daylight hours and negate energy cost savings. Photosensors, timers, and contactors within controllers should be inspected regularly in order to ensure the lighting does not remain on during daylight hours. Lighting control schemes should be reviewed periodically to ensure that non-essential exterior lighting remains off during periods of minimal campus activity, such as holidays.

4.3 Control Methods

A. Photosensors

Photosensors are available with adjustable thresholds for detecting daylight, as well as a time-delay feature to prevent the sensor from turning on exterior lighting during temporarily dark conditions, such as from passing clouds or pedestrians walking by the controller. Manufacturer's recommendations for positioning photosensors should be followed. The photosensor should have a clear view of the sky. The photosensor should not be located next to trees, poles, or other obstructions that may block the sensor's light input and turn on exterior lighting during daylight hours.

B. Timers

Timers for exterior lighting should be of the astronomical type to comply with California Energy Code requirements, and prevent exterior lighting from remaining on during periods of daylight. Astronomical timers self-adjust according to local longitude and latitude, eliminating the need for reprogramming during different periods of darkness throughout the year. Timers should include a battery back-up source to maintain programming during a temporary power outage.

C. Digital Controls

Digital lighting controllers can combine a photosensor and astronomical timer for maximum control flexibility and energy savings. For example, lighting can be configured to turn on at dusk using the photosensor control input, and turn off at midnight using the timer control input. Facilities that are used during the night, such as loading docks, can be programmed to turn on at a certain time of night, and turn off at dawn. Digital controls should include a programming scheme based on day-of-week and day-of-year to reduce lighting use during weekends and holidays.

D. Integration with Campus EMS

Integration of exterior, as well as interior, lighting control with the campus energy management system can provide significant energy savings while simultaneously providing detailed information on lighting use and performance. Controllers should be digitally addressable, and have the capability to be monitored in real-time from a central monitoring station. Controllers should provide the capability to send an alarm regarding a stuck contactor or tripped circuit to the central EMS monitoring station. This alarm will instantly notify maintenance personnel of exterior lights remaining on during daylight hours, or failing to turn on during the night. Use of an addressable lighting controller with the capability to send status and alarm notifications will minimize time spent by maintenance personnel troubleshooting lighting circuits.

5.0 LAMP TYPES

5.1 LED

LED, solid state, lighting technology is rapidly improving. It delivers a very directional beam of light at a very low wattage. While the efficacy of the individual LEDs may not be significantly higher than other, more conventional sources, the efficiency of the entire lamp and luminaire combination is very high because nearly all of the light produced is directed out of the luminaire. LED lamps have a lifetime of 50,000 to as much as 100,000 hours depending on manufacturing quality. They work well for low level, wall mounted lights, indicator lights, and façade wall washing.

5.2 Induction

Induction lamps, also known as electrodeless fluorescent, generate white light for good color rendition, have instant-on capabilities, and have an extremely long lifetime of 100,000 hours (about 20 years of operation during dusk-to-dawn use). Their increased initial cost is typically paid back quickly by the reduced maintenance costs. The high wattage induction lamps (100, 150-165 watts) are suitable for high mounting heights in parking and roadway applications. The lower wattage lamps (55 and 85 watts) are suitable for pedestrian scale luminaires in pedestrian pathway applications.

5.3 Compact Fluorescent

Compact fluorescent sources have the advantages over incandescent sources of longer life and lower energy use. Compact fluorescent lamps have average lifetimes from 10,000-15,000 hours, depending on manufacturing quality and operating conditions. Due to the bulky size and shape of these lamps, they do not perform well as highly directional sources such as floodlights. They work very well for decorative luminaires that create a soft glow or for lighting surfaces or façades.

5.4 Metal Halide

Metal Halide lamps provide white light for better color rendition than High Pressure Sodium lamps. However, Metal Halide lamps require warm-up and re-strike time. These lamps can be used with time switches and photocells, but are not recommended for use with motion sensors due to the time necessary for warm-up. Metal Halide lamps have an average life of 15,000 hours.

5.5 Lamps of Limited or Prohibited Use

High Pressure Sodium (HPS) lamps produce orange light and should not be used on campus due to the poor color rendition, unless their use is mandated by local ordinances. Additionally, mercury vapor, low pressure sodium, and halogen lamps should not be used to a great extent due to their low efficacy (lumens of light output per watt of electricity input) and short life, high heat output. If halogen lamps are used in limited cases, they should be dimmed to extend their life.

Incandescent lamps are prohibited. The average life of an incandescent lamp is only 1,000 hours. They are a very inefficient use of electric energy and are an unsustainable waste of material and resources.