

Bear Valley Visitor Center Lighting Retrofit Guide for National Parks





This guide was developed in partnership with the National Park Service, Point Reyes National Seashore, Bear Valley Visitor Center, and the California Lighting Technology Center at the University of California, Davis.



Contents

Part 1	Introduction 2
	Energy Efficiency in National Parks 4
Part 2	Simple Strategies for Maximum Efficiency 6
Part 3	Lighting Retrofits in National Parks 8
	Lighting Retrofit Case Study: Bear Valley Visitor Center 9
	Lamp and Fixture Recommendations 10
	System Level Retrofits 15
Part 4	Conducting a Lighting Audit 16
	Lighting Audit Log 20
Part 5	Conclusion 22
	Glossary 24
	Resources 28

Part 1

Introduction



“To conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.”

National Park Service Organic Act, 16 U.S.C.1.

Many national parks offer services to visitors in areas that are remote and offer refuge from urban life. Providing basic comforts in our parks, however, often requires electricity, but evidence of humans’ effects on the environment proves that it is imperative to take action to reduce this energy use and protect resources. One highly effective way to reduce our energy consumption is through the integration of energy-efficient lighting technologies.

This lighting handbook was developed by the U.S. National Park Service and the Bear Valley Visitor Center at Point Reyes National Seashore because we are committed to implementing energy-use reduction strategies and lowering carbon emissions through lighting retrofits, photovoltaic systems, and other energy-conscious lighting practices. Such preservation will leave the park unimpaired for future generations to enjoy.

Lighting plays a significant role in the safety and enjoyment of national parks, but in the built environment, this lighting accounts for 20 to 30% of all electricity use. Light quality and energy efficiency can work concurrently to enhance visitors’ stays without interfering with the natural beauty of the scenery and wildlife or using more resources than necessary. And when combined with the right sensors to maximize efficiency without compromising quality, lighting can be vastly improved, typically saving more than 50% in retrofit applications.

This guide aims to assist in the process of integrating energy-efficient lighting technologies as retrofits into national parks, and it offers tips for evaluating light sources, performing a lighting audit, and pairing lamps with lighting controls. During the guide’s development, lighting audits were conducted at the Bear Valley Visitor Center in an effort to identify the most applicable recommendations. This guide is intended to function as an overview of opportunities that exist for lighting improvements in visitor centers in the National Park Service facilities, as well as in other parks throughout the United States.

Energy Efficiency in National Parks

Any size retrofit—from changing one light bulb to upgrading an entire lighting system—can have a positive effect on energy use, costs, pollution, and the visual environment. National parks have a significant opportunity to enhance their facilities for substantial improvements in these areas. The following are reasons to execute a lighting retrofit.

Save energy

Lighting retrofits, focused on upgrades to more efficient and advanced technologies, can greatly reduce energy consumption and lower energy bills, while also maintaining lighting levels and quality. Upgrading technologies also can offer occupants greater control over lighting, allowing for additional energy savings. New lighting technologies, such as light emitting diodes (LEDs), offer high-quality lighting with high light output and low power consumption.

Retrofitting for better efficacy—a lighting term used to quantify how effectively lamps transform electrical power (watts) into visible light (lumens)—will save energy by producing an equal or higher amount of light with the same or lower amount of power consumption.

Reduce maintenance and labor costs

Lighting technology improvements have led to increased lifetimes for components, which translates to fewer failures and reduced maintenance requirements.

Implementing a routine maintenance program in addition to a lighting retrofit will greatly simplify maintenance practices and reduce the operational costs associated with lighting system maintenance.

Improve lighting quality and visual environment

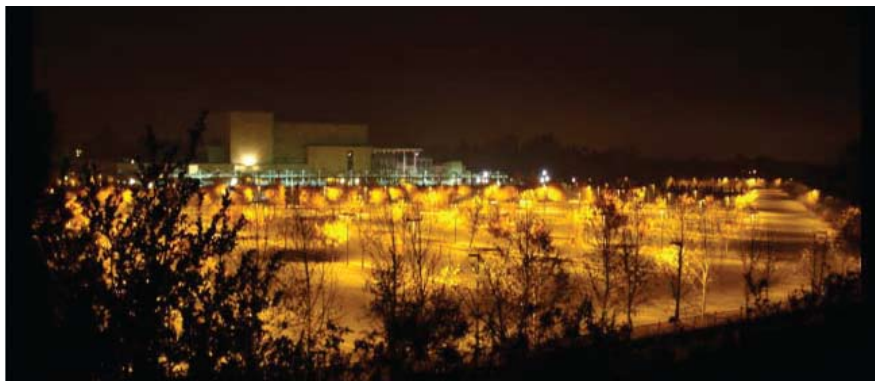
Lighting retrofits can help address general lighting quality problems, and new technologies have improved visual quality characteristics, such as color. When discussing lighting quality, two metrics commonly are used: correlated color temperature (CCT) and color rendering index (CRI).

Reduce toxins

By consuming less electricity, the facility will help reduce the demand and associated emissions from off-site power generation. These harmful emissions include CO₂ and other greenhouse gases. In addition, retrofitting from CFLs to LEDs decreases the facility's mercury footprint and, because of LEDs' long life, reduces the amount of product entering the waste stream.

Reduce light pollution and trespass

Light pollution and trespass also are a concern. Outdoor luminaires that are not properly shielded will project or leak light, deteriorating the view of the night sky. It is estimated that two-thirds of the U.S. population can no longer see the Milky Way with the naked eye. According to the International Dark-Sky Association (IDA), "light pollution is any adverse effect of artificial light, including sky glow, glare, light trespass, light clutter, decreased visibility at night, and energy waste." Similar to light pollution, light trespass results from fixtures that shine light beyond their intended target areas. In parks and other areas where the preservation of natural systems is paramount, light pollution and light trespass produce documented effects on the behavior of many wild species. Therefore, astronomical and ecological light pollution must be addressed when planning a lighting retrofit in ecologically sensitive areas. Proper lighting design will eliminate excess light and preserve the level of darkness needed for the healthy behavior of area inhabitants.



© California Lighting Technology Center, UC Davis

Part 2

Simple Strategies for Maximum Efficiency



When a building-wide retrofit is not a possibility, these quick energy-efficiency tips can help cut costs and reduce greenhouse gases without breaking the bank. These suggestions can be applied to interior and exterior spaces.

Replace incandescent lamps

One simple, energy-efficient practice is to replace incandescent lamps with compact fluorescent lamps. CFLs have shown vast improvement over their predecessors, with a range of correlated color temperatures, improved color rendering, no flicker, and long life. Some modern reflector-style CFLs are designed explicitly for dimming applications. If a CFL is used on a dimming circuit, ensure that it is labeled for that purpose. Also, use Energy Star-labeled products whenever possible.

Turn off luminaires when not in use and install lighting controls

Occupancy sensors can save a significant amount of energy by turning off the lights when a space is vacant. This is perhaps one of the biggest energy-saving opportunities because energy is a function of power and time. Replace an existing light switch with a sensor switch that can fit in the same wall box. Sensors can be manual on or automatic on, but should always automatically turn off the lights. Time-delay periods can be adjusted to maximize savings, and some systems have an integrated LED night-light, which provides added safety.

Reduce electric lighting where daylighting can be used

Reduce energy use by displacing electric lights with daylighting. A single 12-inch-diameter tubular skylight will provide adequate illumination for a 100- to 150-foot space. Natural daylight will reduce the amount of electric light that is used as well as provide high-quality lighting. Automated shading for skylights is available to control daylight when it is not needed. Some tubular daylighting devices include louvers for dimming control and integrated electric lighting that turns on when ample daylight is not available.

Replace T12 fluorescent lamps with T8 or T5 lamps

Many buildings still have T12 fluorescent lamps installed (T refers to tubular lamp, and 12 refers to the diameter in eighths of an inch). Compared to modern T8 and T5 fluorescent lamps, T12 lamps are inefficient and have relatively poor color rendering. Replacing these lamps will increase efficiency, reduce flicker, increase lighting system longevity, and improve color quality within the space.

Part 3

Lighting Retrofits in National Parks



Bear Valley Visitor Center Lamp and Fixture Recommendations

The green boxes in the margins highlight technologies CLTC recommends for the Bear Valley Visitor Center. These technologies aim to achieve both energy savings and an improved visual environment for the BVVC.

Lighting Retrofit Case Study: Bear Valley Visitor Center, Point Reyes National Seashore

Bear Valley Visitor Center (BVVC) provides information on Point Reyes National Seashore's roads, trails, and natural history. The visitor center was designed to blend in with the historically significant ranching culture of the area and is located in the heart of the Olema Valley. The interior exhibit space offers a glimpse of the diverse ecosystems and cultural heritage of the park and includes a seismograph, touch table, auditorium, and book sales area.

The BVVC, built in 1983, has aging lighting technologies throughout the building. Fixtures include a variety of lamps, some of which burn out often and are located in areas that require a 30-foot ladder to reach. The park coordinated with the California Lighting Technology Center at UC Davis to design a lighting renovation. Goals of the renovation were to create a brighter, safer environment for park visitors, while also reducing the amount of electricity used. An emphasis was placed on emerging technologies to reduce the park's carbon output.

The project identified lighting systems, combined with optimal placement, to achieve maximum energy efficiency while maintaining the quality of light recommended for visitor centers and exhibit dioramas. Appropriate lighting controls also were specified, and strategies were developed to set various lighting levels depending on the building's use. These strategies will allow for maximum lighting during public visiting hours, but lower-yet-functional light levels during non-visiting hours, when employees perform maintenance and office activities.

The lighting designs and guidelines developed by CLTC for the BVVC will serve as a model for other National Park Service visitor centers and museums. Point Reyes National Seashore also plans to develop an outreach component at BVVC emphasizing energy efficiency through lighting practices and renewable energy. Public education will focus not only on achieving energy savings at the visitor center, but on how the visiting public can make a difference at home, at the office, and in other aspects of everyday life.

Lamp and Fixture Recommendations

Lamp Replacements

Lamp replacements are the most basic level of retrofit examined for this project. All replacements assume a one-to-one retrofit ratio and are expected to provide an improved visual environment and energy savings.

Ceramic Metal Halide

CMH lamps are best suited for spot and track light applications within the A/V room, main exhibit space, and gift shop.

Ceramic Metal Halide

Ceramic metal halide (CMH) lamps are a relatively new light source. They have a lamp life of 12,000–15,000 hours, work in both enclosed and open fixtures, and provide a high-quality light (3000 K, 80+ CRI). Some also have the added benefit of ballast thermal protection and UV control. They are available in many bases, including the conventional medium Edison base. CMH lamps are ideal replacements for halogen and incandescent spot and track lights because of their longer lamp life and incorporated reflectors.

LED Replacement Lamps



LED replacement lamps are ideal for open spotlighting like those at the BVVC gift shop, pendant luminaires in the A/V room, and any open-air spotlights in the main exhibit space.

◀ EnduraLED A19 Lamp

LED Replacement Lamps

LED replacement lamps, a new long-life, dimmable source, fit into many conventional sockets. Products typically offer at least a 25,000-hour lamp life, are available in numerous colors, and emit virtually no UV light. LED replacement lamps contain no mercury. They can provide large energy savings when compared to incandescent and CFL lamps. Depending on the specific lamp distribution, LED lamp replacements are effective for either general illumination or illumination in spotlights. Most LED lamp replacements are recommended for use only in non-enclosed fixtures.

T8 Lamp and Electronic Ballast

T8 lamp and ballast retrofits are recommended for the BVVC office and mechanical room because of the increased light output and energy and maintenance savings produced by the retrofit, as well as the energy

T8 Lamp and Ballast Retrofit

Existing T12 fluorescent light fixtures, usually paired with magnetic ballasts, can be retrofitted with new T8 lamps and electronic ballasts to produce large energy savings. The retrofit often costs less than purchasing a new luminaire and allows facilities to keep the existing fixtures. Additionally, different types of fluorescent ballast retrofits (dimming, step-dimming, and digitally addressable) are available, which facilitates more advanced controls strategies. T8 lamps provide increased light output and decreased power consumption and cost. T8 lamps have a 24,000- to 36,000-hour lifespan and come in a wide variety of sizes, color temperatures, and CRIs.

LED Downlights at the Bidwell Mansion Visitors Center in Chico, CA

More than 800 million recessed downlights are in operation in the United States, with about 83% still using incandescent lamps. Significant energy savings potential exists for long-life LED replacements, which last up to 25 times longer and use significantly less energy.

The Bidwell Mansion Visitors Center replaced existing fluorescent technologies with **HALO® LED recessed downlights**, resulting in 51% energy savings and an annual greenhouse gas emissions reduction of 560 pounds.

LED Downlight

LED downlights come in a wide array of color temperatures (2700–5000 K) and high CRIs (80+). Depending on the manufacturer, fixture wattages, light output, and trim can vary. The LED modules themselves generally have a lifetime of at least 50,000 hours. Wattages vary between manufacturers and models, but energy consumption per downlight generally is 10–20 W. Some LED downlights have the added benefit of being dimmable. Check the manufacturer recommendations on dimmer compatibility, especially when pairing LED downlights with existing dimmers. Additionally, the long lamp life, when compared with the 8,000–12,000-hour lamp life of CFLs, provides maintenance savings. The use of LED sources also eliminates the need for mercury disposal because LEDs do not contain mercury as CFLs do.

LED Spot and Track Lights

Because LEDs are point sources, LED spotlights produce a tight beam of light necessary for the dioramas, without the high energy consumption associated with incandescent sources or unfocused light distribution currently experienced with CFLs. Energy consumption is between 10–20 W, with light output that is similar to a 26 W CFL. However, because of the tight beam of light, the LED spotlight provides more light where it is intended, which may allow for much smaller wattage replacements. Additionally, the LEDs are dimmable and available in 3000 K or 4000 K color temperatures with a CRI of 80.

LED Cove Light

LED cove lighting illuminates spaces indirectly using an energy-efficient LED linear fixture with a 50,000-hour lifespan. The fixtures are dimmable, and the LEDs produce a high-quality, cool, white light. Cove lights generally are positioned out of sight along ledges, edges, and around other recessed areas of the ceiling. Cove lighting helps accentuate architectural elements without producing glare.

LED Downlights

LED downlights are recommended for both the A/V hallway and the projector room. The use of LED downlights in these spaces will provide energy savings and higher light levels because of the high fixture efficiency of many LED products.

LED Spot and Track Lights

LED spot and track lights are recommended for the A/V room, A/V hallway, and main exhibit space and gift shop. Energy savings from one-to-one retrofits may be surpassed by removing some fixtures outright because of the increased fixture efficiency and tight beam angles of the LED products.

LED Cove Lights

LED cove lights are recommended for kiosks, where dimmable, linear LED luminaires would replace CFL track lighting. This would increase the energy efficiency and decrease the mercury footprint of the building, while also avoiding overillumination of the kiosks and surrounding areas.

LED Gooseneck Lighting

LED gooseneck lighting is recommended to replace CFL fixtures at BVVC to provide energy savings and decreased maintenance costs. The LED gooseneck fixtures are best suited for the space because of the decorative nature of the existing fixtures. The current luminaires do not have lenses and are not protected from the elements, and as a result, the lamps have to be cleaned periodically to maintain maximum light output.

Bi-level Exterior Fluorescent Luminaires

The bi-level exterior fluorescent luminaire is recommended for BVVC's exterior bulletin board to provide energy-efficient lighting in an irregularly occupied space.

LED Gooseneck Lighting

Gooseneck fixtures are available in a wide array of styles, colors, and light sources. Depending on the manufacturer, LED gooseneck fixtures consume either 10 W or 18 W of power and have about a 50,000–60,000-hour lifespan. The fixtures can be ordered with lenses to protect the light sources from the elements. Maximum energy savings should be pursued while still preserving the architectural elements or the pre-existing lighting. The reduction in maintenance costs from improved lamp lifetimes for exterior lighting will be an added benefit, as will the reduction of another mercury source.

Bi-level Exterior Fluorescent Luminaires

The bi-level exterior fluorescent luminaire is available in both 2' and 4' sizes. It is rated for exterior conditions and contains an occupancy sensor that allows for energy savings in areas with low occupancy. Depending on ballast choices and size, the fixture can be set to consume as little as 10% of its total energy use while the area is unoccupied. Further energy savings are dependent on lamp choice and occupancy levels.

Lighting Controls

Lighting controls allow for energy savings from environmental factors or usage patterns. Some controls systems can be installed and produce energy savings without any modification to existing lamps and ballasts. Others require systemwide retrofits but produce deep energy savings.

Daylighting Controls

Daylighting controls are recommended for the BVVC office because of its large windows. Additionally, BVVC personnel do not use some of the building's existing lights during parts of the day because of overillumination, although at other times the space appears dim. The combination of a lamp-and-ballast retrofit and daylighting controls in these spaces would allow illuminance levels to be maintained.

Daylighting Controls

Daylighting systems are designed to dim or extinguish interior lights as daylight infiltration increases. By setting a band of acceptable illuminance levels for a space, light levels are maintained while electric lighting is minimized. When combined with occupancy sensors, daylighting controls capture a majority of the potential energy savings achievable through lighting controls.

Wall Switches with Integrated Occupancy Sensors

Occupancy controls are recommended for areas that are not continually in use. Sensors in these areas provide energy savings based on true occupancy and reduce energy waste.

WattStopper CS-350-N PIR Dual Relay Vacancy Sensor provides automatic shutoff for applications that require separate switching. ►



Occupancy Controls

Wall switches with integrated occupancy sensors provide the ability to gain energy savings that might otherwise be lost because of incorrect use. Wall switch sensors use either passive infrared (PIR) or ultrasonic sensors to determine when a space is occupied. Depending on the space, dual-technology wall switches may be necessary. Occupancy-controlled wall switches generally use a manual-on and automatic-off feature. Occupancy sensors also come in centralized ceiling-mounted models. These sensors may require additional wiring but generally provide better coverage, and they may be combined with other occupancy sensors to cover large areas.

Networked Lighting Systems

Networked lighting systems provide the ability to control and manage lights from any location in a building. A gateway serves as the central computing hub, which wirelessly receives data from sources such as occupancy and daylighting controls and sends commands to individual light fixtures. As a result, the gateway is able to maintain desired lighting conditions while still receiving user input from the lighting system. For example, the gateway can maintain light levels in an office with a daylighting sensor, but then have light levels dynamically reduced or increased from a wall-mounted or hand-held remote. Each light connected to the system is individually addressable.

Occupancy Controls

Occupancy controls are recommended for areas of the BVVC that are not continually in use, such as the projector room, the A/V room and hallway, the kitchen, and the public bathrooms.

Wireless Controls

Wireless controls are recommended for the office, dioramas, and exhibits. As the dioramas and exhibits change within the main exhibit space, the lighting in the space can be adjusted accordingly. Lights can be turned on, off, or dimmed to provide appropriate lighting levels.

Bi-level LED Bollards at the California Department of Public Health in Richmond, CA

The California Department of Public Health replaced 18 CFL bollards with nine bi-level **Philips Gardco 830 series LED Bollards** in a two-to-one replacement.

Post-retrofit monitoring conducted over a five-week period yielded 10% pathway occupancy rate. At this rate, the LED bollards consumed 78% less energy than the original luminaires, while providing the same average light levels. In addition, lamp lifetime increased from 10,000 hours to 70,000 hours, resulting in reduced maintenance costs.

Bi-level LED Bollards

Bi-level LED bollards may be a useful, energy-efficient lighting solution because of extremely low occupancy levels expected at the BVVC at night.

LED Step Lights

LED step lights may be useful in exterior stairways as well as to illuminate walls during A/V operations.

Exterior Handrail Lighting

Exterior handrail lighting is an efficient way to provide more light around exterior stairwells for additional safety.

Exterior Pathway Lighting

Bi-level LED Bollards

Bollards provide pedestrians localized lighting in walkway and grounds applications and serve as visual anchors to the surrounding area. Bi-level LED bollards combines long-life, low-energy consumption, and dynamic light output based on occupancy. It operates at 50% of full output during vacant night hours and 100% only when pedestrians are present in the area. When spaces are vacant, the bollard intelligently reduces light levels.

LED Step Lights

LED step lights provide illuminance for aisleways, stairways, and other interior and exterior applications. Step lights consume minimal power and provide options for customization to fit the architectural design.

Exterior Handrail Lighting

Depending on the material of the handrails and the light source desired, a number of designs and manufactures of handrail lighting exist. In most cases, the desired handrail material is aluminum and the light source is either a T8 or T5HO fluorescent lamp or linear LED. LED light sources generally have a 50,000-hour lifespan and a color temperature between 2700K and 5000K. Fluorescent lamps have a lifespan between 24,000 and 36,000 hours with a variety of color temperatures and CRIs.

System Level Retrofits

The following recommendations address lighting retrofits as a complete system change. These retrofits are aimed at achieving deep energy savings in certain spaces throughout the BVVC, while simultaneously providing flexible, occupant-specified lighting levels.

Office

A task-ambient retrofit would provide the largest energy savings for an office, which traditionally relies only on ceiling-mounted luminaires for general lighting, compromising energy efficiency and lighting quality. The Integrated Office Lighting System (IOLS), a combination of energy-efficient LED task lighting and reduced ambient lighting levels, not only would save energy, but also would provide occupants with the flexibility to determine their individual task light levels. Reduced ambient light levels may be achieved with a simple lamp and ballast retrofit. The energy-efficient task lighting would provide large energy savings when compared with incumbent task lighting and also can be configured to use a personal occupancy sensor, which increases energy savings by extinguishing task lighting when work stations are vacant. Additionally, when coupled with networked lighting systems, the occupancy sensor can be linked with the ambient lighting, which maximizes energy savings.

Visitor Information and Camping Registration

To provide illumination without glare, wall-mounted and pendant-mounted direct/indirect fluorescent fixtures can be used over information and registration desks. The fixtures provide low-profile uniform illumination and also can include daylighting sensors to prevent unnecessary illumination during the brighter hours of the day.

Audio/Visual Room

Dimmable linear direct/indirect T8 fluorescent fixtures installed in an A/V room provide uniform illuminance throughout the room, as well as upward illumination to light the ceiling. Additionally, an occupancy sensor could be included to minimize lighting energy use when the space is vacant. The recommended lighting system will consume more energy than the existing lighting does if it is left on 100% of the operating time; however, the occupancy sensor will reduce usage and the new system will provide superior illumination and flexibility when compared to the incumbent lighting.

Integrated Office Lighting System (IOLS)

An Integrated Office Lighting System is recommended for a systemwide retrofit of the BVVC office.

Direct / Indirect Fluorescent Luminaires

Wall-mounted and pendant-mounted direct/indirect fluorescent fixtures would be best suited for the information desk, which currently consists of down-oriented CFLs on a track, and the camping registration desk, which receives minor illumination from gooseneck fixtures oriented toward a bulletin board.

Dimmable Luminaires

Dimmable linear direct/indirect T8 fluorescent luminaires are recommended for the A/V room. The room currently is lit by pendant-mounted fixtures with CFLs. The lamps originally were incandescent but were replaced by CFLs for energy savings. As a result, the luminaires no longer are dimmable by the original incandescent dimmer.

In addition, an A/V exhibit is installed in the room. The recommended luminaires would provide multiple options for the various room uses.

Part 4

Conducting a Lighting Audit



Lighting Evaluation Basics

Whether retrofitting an existing lighting system or designing a new one, a few issues should be addressed before any new lighting components are selected:

- What is the intended lighting application, and what are the required color temperature and color rendering requirements? In other words, how important is it to have colors appear naturally within the desired lighting space?
- Where will the light fixture be located, and if it is outside, what are the cutoff, glare reduction, and spectral considerations of the site? Are there any buildings, roadways, or walkways that would require shielding of direct light, and are any observatories nearby?
- How will the lighting system operate, and what control schemes are best for the application? Can lights be fully extinguished during certain parts of the night?
- What technologies are available to achieve the desired design? If this is not known, what resources are available to find out?

Why conduct a lighting audit

Lighting audits are essential to efficiently determine the current state of a particular lighting system or the need for a new one. An audit of the existing lighting system can determine what type of retrofit is proper. This includes deciding if adding occupancy-based controls, dimming capabilities, or daylight contributions into the new lighting design is appropriate. Lighting audits also allow for an accurate economic evaluation and light level comparison for the pre- and post-retrofit systems. These evaluations become important when seeking additional funding for the project.

How to conduct a lighting audit

Many organizations provide professional services for large-scale lighting system audits, and the processes for each individual audit vary. Several points recommended for an audit are provided in the following section.

Lighting Audit Guidelines

To conduct a thorough evaluation of the existing lighting system or of a potential space, the following items are recommended for consideration:

- The age, condition, quality, and location of existing lighting fixtures, noting any lens discoloration, lens cracking, paint cracking, or burn marks.
- Model and manufacturer of lighting system to obtain existing photometrics.
- Lamp wattage and ballast type.
- Observe the operational environment of the lighting system, noting the possibility of particulate, moisture, or dirt buildup in or around the lighting fixture.
- Note the activities of and the type of work being conducted in the space, as well as any special visual requirements.
- Observe how the lighting system is controlled and how often it is used.
- Note the perceived color of objects or within the space to characterize color quality.
- Measure the physical layout of the existing lighting system noting luminaire height and spacing.
- Use an illuminance meter to measure the light intensity of an existing exterior system during dark sky conditions to determine if the existing design is appropriate for the space. Readings should be taken on the ground and at even intervals to create a “grid” of measurements. These illuminance levels can be compared to the recommended levels for the application. Illuminance meters may be available through tool lending libraries operated by local utilities.

Once all this basic information has been recorded, it is possible to make some useful conclusions about the existing lighting system or space:

- Does the lighting system meet the original or proposed lighting needs of the space and occupants, given the required operations (energy use) and maintenance costs?
- Calculate the system efficacy of each type of luminaire. How efficient is each system at delivering light to its intended surface?
- Calculate the theoretical system illumination, determined from a rough lumen method or point-to-point calculation. Use lighting design software to determine if the theoretical measurements match the measured illumination values from the site. This will help determine the level of deterioration of the current lighting system as well as if the system meets code requirements.
- Calculate the existing lighting power density and determine if it meets any applicable codes or energy standards.

Lighting System Power and Energy Use Estimation

1. COMPUTE THE TOTAL POWER (KW) USED BY THE EXISTING SYSTEM.

EXISTING LAMP OR LUMINAIRE WATTAGE		NUMBER OF LAMPS		TOTAL POWER CONSUMED
_____ W	x	_____ lamps	=	W

2. COMPUTE THE TOTAL ENERGY (KWH) CONSUMED ANNUALLY BY THE EXISTING SYSTEM.

TOTAL POWER CONSUMED BY SYSTEM LUMINAIRE		HOURS OF USE PER DAY		DAYS OF USE PER WEEK		WEEKS OF USE PER YEAR		TOTAL ENERGY CONSUMED
_____ W	x	_____ hrs/day	x	_____ days/wk	x	_____ wks/yr	=	kWh/yr

3. COMPUTE THE TOTAL ENERGY COST (DOLLARS) ANNUALLY FOR OPERATION OF THE EXISTING SYSTEM.

TOTAL ENERGY CONSUMED		ENERGY RATE		TOTAL COST
_____ kWh/yr	x	_____ \$/kWh	=	\$/yr

Lighting Audit Log

FIXTURE / LENSES				
Item Number	Location Description	Age	Condition (soiled, cracked, etc.)	

LAMP

[illegible]

Part 5

Conclusion



Energy-efficient lighting technology is improving and changing rapidly. This means that any retrofit or new construction project should not only meet the baseline and conform to applicable regulations, but facilities managers also should strive to be forward thinking as they plan their designs. Too often, simple paybacks drive decisions and ignore many energy-savings opportunities. The focus should be on the deepest and most sustainable energy-saving approaches, as opposed to short-term economic considerations.

Best practices for a retrofit and design

A lighting project should be easier to plan and manage by following the tips and guidelines in this handbook, making the facility more energy efficient when the project is finished. As more consumers, businesses, and agencies choose energy-efficient lighting sources and integrate intelligent controls systems, technologies will become more affordable, more options will become available, and less energy will be required to light buildings.

Glossary

A

Accent lighting: Lighting used to emphasize or draw attention to a special object or building.

Ambient light: The general overall level of lighting in an area.

B

Baffle: An opaque or translucent element to shield a light source from direct view.

Ballast: A device used with a discharge lamp to obtain the necessary voltage, current, and / or wave form for starting and operating the lamp.

Beam spread: The angle created by two points of equal light intensity on either side of the beam's axis and the point where the axis and lamp surface intersect.

Brightness: Strength of the sensation that results from viewing surfaces from which the light comes to the eye.

Bulb or lamp: The source of electric light. To be distinguished from the whole assembly (see luminaire). Lamp often is used to denote the bulb and its housing.

C

Candela (cd): Standard SI unit of luminous intensity, or candle power. One candela is one lumen per steradian. Formerly called the candle.

Candlepower distribution: The plot graph representation of the variation in light spread and intensity of a lamp or luminaire.

Color Rendering Index (CRI):

The CRI rating indicates how well an object's color(s) are rendered by a light source. It is a comparison of eight specific test colors between an "ideal" light source (incandescent or daylight) and the light source in question. The apparent shifting of these test colors is measured to give an average color rendering ability of a lamp. The greater the apparent shift, the lower the CRI. The CRI scale ranges from 0 (does not render colors well) to 100 (matched color rendition to that of the ideal source). If color rendering is less important, a CRI in the mid 70s may be less expensive and / or more efficient and sufficient. On the other hand, if color rendering is extremely important, it might be appropriate to sacrifice cost and / or efficiency for a CRI in the 90s. A CRI in the 80s is standard and should be specified for most applications.

Correlated Color Temperature

(CCT): CCT is measured in Kelvin temperature, which is a reference to the color produced by blackbody emitters (such as stars) when they are heated to different Kelvin temperatures. As these emitters become hotter, they move from appearing orange to white to blue. In lighting, this can be confusing because light sources that are commonly referred to as "cool" are more blue and thus have a higher Kelvin temperature than "warm" — more orange light sources. Typically, an acceptable CCT range for indoor environments is between 2500K and 5000K. Warm lighting (which has a low CCT) helps to create a homey and cozy space, while cool lighting (with high CCT) is associated more with commercial environments.

Cutoff angle of a luminaire:

The angle, measured up from the nadir (i.e. straight down), between the vertical axis and the first line of sight at which the bare source (the bulb or lamp) is not visible.

Cutoff fixture: A fixture that provides a cutoff (shielding) of the emitted light.

D

Dark adaptation: The process by which the eye becomes adapted to a luminance less than about 0.03 candela per square meter (0.01 footlambert).

Disability glare: See "Glare."

Discomfort glare: Glare that produces discomfort, but does not necessarily diminish visual performance.

E

Efficacy: A measure of how effectively a desired effect is achieved, also called "luminous efficacy." For lighting, it is used to quantify how effectively lamps transform electrical power (watts) into visible light (lumens). A lamp that consumes 100 W of power and produces 2000 lm would have an efficacy of 2000 lm / 100 W or 20 lm / W. For white, high-brightness LEDs, luminous efficacy published by LED manufacturers typically refers to the LED chip only, and doesn't include driver losses. It is important to consider the entire system when evaluating LED fixture efficacy.

Efficiency: A measure of the effective or useful output of a system compared to the input of the system, also called “luminaire efficiency.” Often expressed as a percentage of how much energy a system provides compared to the amount of energy supplied to it.

Energy (radiant energy): Unit is erg, or joule, or kWh.

F

Fixture: The assembly that holds the lamp in a lighting system. It includes the elements designed to give light output control, such as a reflector (mirror) or refractor (lens), the ballast, housing, and the attachment parts.

Floodlight: A fixture designed to “flood” a well-defined area with light with a beam angle of 30° or more.

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

Flux (radiant flux): The flow rate of energy moving a certain distance from a source. Unit is erg/sec or watts.

Footcandle: Illuminance produced on a surface one foot from a uniform point source of one candela.

Full-cutoff fixture: A fixture that allows no emission above a horizontal plane through the fixture.

G

General illumination: A term used to distinguish between lighting that illuminates tasks, spaces, or objects from lighting used in indicator or purely decorative applications. In most cases, general illumination is provided by white light sources, including incandescent, fluorescent, and white LEDs. Lighting used for indication or decoration often is monochromatic, as in traffic lights, exit signs, vehicle brake lights, signage, and holiday lights.

Glare: Intense and blinding light resulting in reduced visual performance and visibility, often accompanied by discomfort.

Group relamping: The practice of replacing lamps on a routine scheduled basis determined by a percentage of estimated lamp life.

H

High intensity discharge (HID) lamp: In a discharge lamp, the emitted energy (light) is produced by the passage of an electric current through a gas. HID lamps include mercury, metal halide, and high pressure sodium lamps. Other discharge lamps are low pressure sodium and fluorescent. Some such lamps have internal coatings to convert some of the ultraviolet energy emitted by the gas discharge into visual output.

High Pressure Sodium (HPS) lamp: An HID lamp where radiation is produced from sodium vapor at relatively high partial pressures (100 torr). HPS essentially is a “point source.”

I

Illuminance: The amount of visible light that falls on a surface is referred to as illuminance. Technically, the illuminance on a surface is the density of luminous flux falling or striking that surface. The units of illuminance are lumens per square foot or footcandles (fc). The metric units for illuminance are lumens per square meter or lux. One fc is equal to 10.76 lux, although a 1 fc = 10 lux approximation is commonly made by lighting practitioners. Typical illuminance levels or footcandles are recommended for different visual activities. Recommended number of footcandles for a space refers to the average light level required for a particular task measured in the horizontal plane at desk height. Vertical footcandles is illuminance on vertical surfaces, such as walls. Recommendations for illuminance levels can vary greatly depending on location and types of tasks performed.

Illuminating Engineering Society of North America (IES): The professional society of lighting engineers, including those from manufacturing companies, and others professionally involved in lighting.

Incandescent lamp: An electric lamp in which a filament gives off light when heated by an electric current.

Indirect fixture: A fixture that directs the majority of its luminous flux in an upward direction.

Infrared radiation: EM radiation just to the long wavelength side of the visual.

Intensity: The degree or amount of energy or light.

International Dark-Sky

Association (IDA): A nonprofit organization whose goals are to build awareness of the value of dark skies and of the need for quality lighting.

IR Lamp: Infrared lamps feature a coating that recycles the wasted heat generated by the filament. This coating allows visible light to pass through it while reflecting infrared heat back to the filament, making the lamp more efficient.

K

Kilowatt-hour (kWh): A unit of energy equal to the work done by one kilowatt (1000 W) of power acting for one hour.

L

Light pollution: Any adverse effect of manmade light. Often used to denote urban sky glow.

Light trespass: Light falling where it is not wanted or needed; spill light; obtrusive light.

Light Emitting Diode (LED):

A semiconducting device made of inorganic (noncarbon-based) material that produces light when an electric current flows through it. LEDs first were developed in the 1960s but were used only in indicator applications until recently.

Low Pressure Sodium (LPS) lamp:

A discharge lamp where the light is produced by radiation from sodium vapor at a relatively low partial pressure (about 0.001 torr). LPS is a tube source. It is monochromatic light.

Lumen depreciation factor:

Light loss of a luminaire over time because of the lamp's decrease in efficiency, dirt accumulation, and any other factors that lower the effective output.

Lumen maintenance: Ability of a source to maintain a given percentage of its original lumen output expressed in percentage of total lifetime.

Lumen: The unit of measurement of the amount of light, also known as luminous flux, produced by a light source.

Luminaire: A complete lighting unit consisting of a lamp and the parts designed to distribute the light (lens, reflector), to position and protect the lamp (housing), and to connect the lamp to the power supply (ballast, transformer). Also referred to as a lighting fixture or light fixture.

Luminance: The amount of visible light coming off a surface is referred to as luminance. The luminance of a source or surface is defined as the intensity of the source or surface in the direction of an observer divided by the area of the source or surface seen by the observer. This directionality is important to consider, as a source or surface often will have a luminance that varies depending on the angle from which it is viewed. The units of luminance are candelas per square inch, or per square foot in the English (inch-pound) system, and candelas per square meter in the metric (SI) system.

Luminous Flux: Lumens are the unit of luminous flux, or visible light, produced by a light source. In a simplistic model: A lamp receives power (watts) and emits light (lumens).

Lux: One lumen per square meter. Unit of illuminance.

M

Mercury lamp: An HID lamp where the light is produced by radiation from mercury vapor.

Metal halide lamp: An HID lamp in which the majority of the light is generated through the radiation of metal halide vapors.

Mounting height: The height of the fixture or lamp above the ground.

O

Organic Light Emitting Diode

(OLED): OLEDs are based on organic (carbon-based) materials. In contrast to LEDs, which are small point sources, OLEDs are made in sheets, which provide a diffuse area light source. OLED technology is developing rapidly and is increasingly used in display applications such as cell phones and PDA screens. However, as of the time this guide was published OLEDs are still a few years away from becoming a practical general illumination source. Additional advancements are needed in light output, color, efficiency, cost, and useful lifespan.

P

PAR lamp: Lamp with a parabolic aluminized reflector.

Phosphor conversion: A method used to generate white light with LEDs. A blue or near-ultraviolet LED is coated with a yellow or multichromatic phosphor, resulting in white light.

Photometry: The quantitative measurement of light level and distribution.

Q

Quality of light: A subjective ratio of the pluses to the minuses of any lighting installation.

R

Reflector lamp: Lamp in which the outer blown glass bulb is coated with a reflecting material that helps direct the light.

Reflector: Controlling light output by means of reflection (mirror).

Refractor: Controlling light output by means of refraction (lens).

RGB: RGB is an acronym for red, green, and blue, the three primary colors of light. When the primaries are mixed, the resulting light appears white to the human eye. Mixing the light from red, green, and blue in LEDs is one way to produce white light. The other approach is known as phosphor conversion.

S

Semi-cutoff fixture: A fixture that provides some cutoff, but less than a full-cutoff fixture.

Solid-State Lighting

(SSL): Technology that uses semiconducting materials to convert electricity into light. SSL is an umbrella term encompassing both light emitting diodes (LEDs) and organic light emitting diodes (OLEDs).

Spot relamping: Practice of replacing lamps as they burn out.

Spotlight: A fixture designed to light only a small, well-defined area with a beam angle of 12 degrees or less.

Stray light: Emitted light that falls away from the area where it is needed or wanted. Light trespass.

T

T# (T8, T12, etc.): T stands for tubular, the number pertains to the diameter of the tube in 1/8th-inch increments. A T8 lamp is 8/8 of an inch or a 1-inch diameter, a T12 lamp has a diameter of 12/8 or one-and-a-half inches. 38-mm diameter fluorescent lamps include specialized models for work premises with low temperature applications (exterior lighting, refrigerated warehouse).

U

Ultraviolet light: The energy output by a source that is of shorter wavelengths than the eye can see. Some photographic films are sensitive to ultraviolet energy, as are many electronic detectors. Black Light.

Urban sky glow: The brightening of the night sky as a result of manmade lighting.

V

Visibility: Being perceived by the eye. Seeing effectively. The goal of night lighting.

Resources

Resources included in this section are intended to be used as a preliminary guide for information on lighting. Though it is not a complete list, each of the resources included here provides links to a wide range of materials on this subject as well as related topics. The information contained here is up to date at the time this guide was created.

U.S. Department of Energy **www.energy.gov**

The Department of Energy's overarching mission is to advance the national, economic, and energy security of the United States; to promote scientific and technological innovation in support of that mission; and to ensure the environmental cleanup of the national nuclear weapons complex.

Exterior Lighting Guide

This guide for federal agencies provides an overview of exterior lighting technologies that would best be integrated into national parks as retrofits or new designs, as well as tips for evaluating light sources, performing a lighting audit, and pairing lamps with lighting controls.

Lighting Retrofit Workbook **https://www1.eere.energy.gov/femp/pdfs/NPS_guidebook.pdf**

This guide for National Park Service Visitor Centers is designed to maximize lighting energy savings while maintaining or improving the lighting quality of the park.

Lighting Handbook and Retrofit Guide **http://cltc.ucdavis.edu/images/_downloads/forest_service_lighting_handbook_and_retrofit_guide.pdf**

This handbook aims to assist in the process of developing high-performance, energy-efficient, quality lighting retrofits for the Forest Service community.

California Lighting Technology Center, UC Davis **cltc.ucdavis.edu**

The California Lighting Technology Center's (CLTC) mission is to stimulate, facilitate, and accelerate the development and commercialization of energy-efficient lighting and daylighting technologies. This is accomplished through technology development and demonstrations as well as outreach and education activities in partnership with utilities, lighting manufacturers, end users, builders, designers, researchers, academics, and government agencies.

U.S. National Park Service **www.nps.gov**

Since 1916, the American people have entrusted the National Park Service with the care of their national parks. With the help of volunteers and park partners, the National Park Service is proud to safeguard these nearly 400 places and to share their stories with more than 275 million visitors every year.

National Park Service Night Sky Team **www.nature.nps.gov/air/lightscapes/team.cfm**

The National Park Service Night Sky Team was formed in response to the alarming increase of light pollution even in national parks. The team works across the country to document the effects of light pollution.

Lawrence Berkeley National Laboratory **www.lbl.gov**

Berkeley Lab is a member of the National Laboratory System supported by the U.S. Department of Energy through its Office of Science. It is managed by the University of California (UC) and is charged with conducting unclassified research across a wide range of scientific disciplines.

