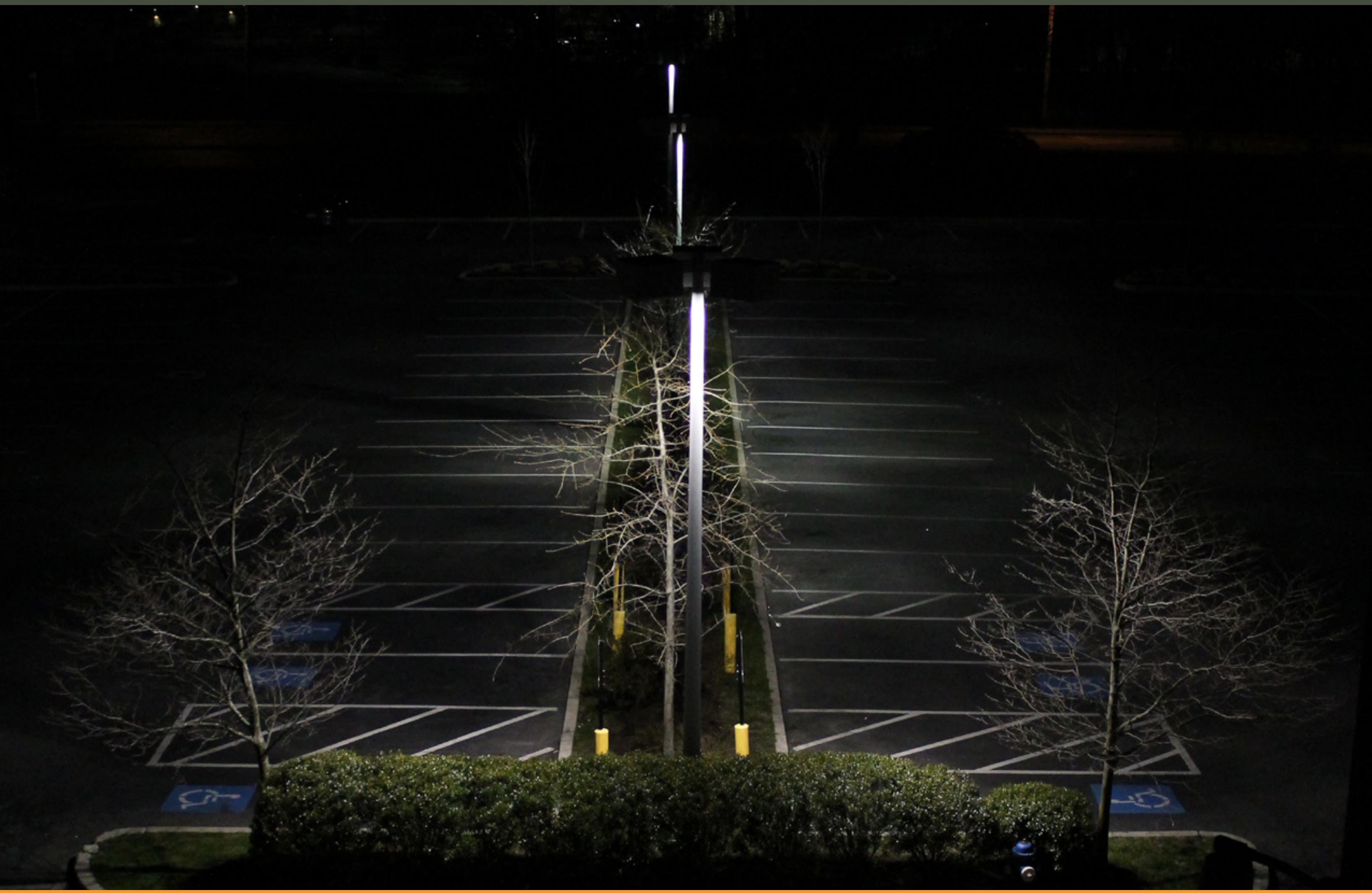
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



GUIDE TO FEMP-DESIGNATED PARKING LOT LIGHTING

FOR FEDERAL AGENCIES

FEMP
Federal Energy Management Program

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INTRODUCTION

Legislation and the Federal Acquisition Regulations (FAR) require federal agencies to specify and buy ENERGY STAR® qualified products or, in categories not included in the ENERGY STAR program, products that meet or exceed efficiency requirements designated by the Federal Energy Management Program (FEMP). Agencies that follow requirements to buy efficient products can realize substantial operating cost savings and reduce pollution. As the world's largest consumer, the federal government can help lead the entire U.S. market to achieve greater energy efficiency while saving taxpayer dollars.

FEMP provides acquisition guidance and federal efficiency requirements across a variety of product categories, including outdoor pole-arm-mounted area and roadway luminaires, which are a FEMP-designated product category. Federal laws and executive orders mandate that agencies meet these efficiency requirements in all procurement and acquisition actions that are not specifically exempted by law.

The purpose of this guide is to explain in greater detail the FEMP-designated outdoor pole/arm-mounted area and roadway product category, to show how the equipment can be used to maximize total energy efficiency (using the metrics defined below), and to provide an estimate of the cost effectiveness of using FEMP-designated products.

ENERGY EFFICIENCY METRICS

There are different energy efficiency metrics. Although there are several metrics to describe energy efficiency, here we consider three lighting-specific metrics: efficiency (very simple), efficacy (simple), and lighting power density (complex). This guide primarily focuses on efficacy, and demonstrates how efficacy incorporated with other elements can reduce power densities.

Efficiency

Efficiency is a measure of how effectively a device converts input into output. Luminaire efficiency (LE) is the light leaving the luminaire divided by the light generated by the bare lamp (light bulb) when operated outside of the luminaire. Because both values (the light leaving the luminaire and the light generated by the light source[s]) have the same unit, luminaire efficiency is therefore a unitless ratio.

Efficacy

Efficacy is the capacity to produce an effect. In lighting, efficacy is measured in lumens per watt (lm/W, also abbreviated LPW). Efficacy can apply to light sources or luminaires. The greater the efficacy, the more light is generated for the same watts. Most people are familiar with this metric related to vehicles; for example, a car that gets 30 miles per gallon is more efficacious than a car that gets 25 miles per gallon.

FEMP's designated product for lighting focuses on luminaire efficacy and uses the term luminaire efficacy rating (LER). The following page explains how to calculate the LER as well as the relationship between luminaire efficiency and luminaire efficacy.

A key note regarding efficacy is that it counts the emitted lumens irrespective of the direction in which they are emitted, or the usefulness of those lumens. A luminaire can have a lower LER but do a better job of distributing light to an identified task.

Lighting Power Density

Lighting power density (LPD) is the total input power (*i.e.,* including the driver or ballast) multiplied by the total number of luminaires divided by the area in which the equipment is installed. Many energy codes use this metric; however, it does not actually focus on *energy*. Energy is power multiplied by time, so it is important to distinguish between power (watts) and energy (watt-hours). Lighting power density calculations do not indicate any energy savings as a result of the use of lighting controls.

FEMP-DESIGNATED PRODUCTS

As of September 2013, there are FEMP-designated products for lamps (light bulbs), ballasts, interior fluorescent luminaires, industrial high-bay luminaires, and many exterior luminaires. The metric for luminaires is the LER. The following provides the LER value for parking lot luminaires (classified within FEMP as outdoor pole/arm-mounted area and roadway luminaires) as well as helpful calculations.

FEMP REQUIREMENTS FOR PARKING LOT LUMINAIRES

Outdoor pole/arm-mounted area and roadway luminaires must have an LER of 65 to be FEMP-designated (as of the date of this publication; the most current value as well as FEMP-designated products can be found at Covered Product Category: Exterior Lighting). The following explains how to calculate LER for conventional light sources such as fluorescent, metal halide, and induction lighting, as well as light-emitting diode (LED) luminaires.

$$\text{LER} = \frac{\text{total light leaving the luminaire}}{\text{input power}}$$

Conventional Luminaires

Conventional luminaires (non-LED) can use different combinations of lamps, ballasts, and optics; often requiring LER to be calculated. If an LER is not available, buyers may estimate the LER using this formula:

$$\text{LER} = \frac{\text{luminaire efficiency x lamp lumens}}{\text{lamp+ballast input watts}}$$

LE x lamp lumens, and lamp+ballast (system) input watts are typically found in manufacturers' product catalogs and photometric reports.

The LER formula may be used with generally available component performance data to determine the minimum performance of other components. For example, known values may be used to calculate the lowest LE necessary to meet an LER requirement:

> A 200-watt high-pressure sodium (HPS) lamp produces 22,000 initial lumens with 230 lamp+ballast input watts. What LE is necessary to meet the minimum required LER of 65?

$$\text{LE} = \frac{\text{LER} \times \text{lamp+ballast input watts}}{\text{lamp lumens}} = \frac{65 \text{ lm/W} \times 230 \text{ W}}{22{,}000 \text{ lumens}} = 0.68$$

Therefore, for a minimum required LER of 65, a fixture combined with the lamp and ballast values provided must have an LE of at least 68%.

LED Luminaires

LED luminaires are available in different combinations, but their values are reported for the complete luminaire, not the light source by itself. The complete LED housing includes the fixture, light source (or lamp), and driver (similar to a fluorescent ballast). If an LER is not available, buyers may calculate the LER for LED luminaires using this formula:

$$\text{LER} = \frac{\text{luminaire light output (lumens)}}{\text{input power (watts)}}$$

DESIGN PROCESS

The rest of this document will explain options for energy efficient lighting in parking lots using FEMP-designated luminaires and features accounting for both lighting quality and energy efficiency. Selecting energy efficient equipment, such as FEMP-designated equipment, is the first step in energy efficient parking lot lighting. This section address a step-by-step process from surveying the site to installation. Key points of the following design process section include:

1. Developing an inventory of equipment
2. Determining lighting quality and quantity needs
3. Incorporating lighting controls
4. Addressing cost effectiveness in the process

STEP 1: CONDUCT COMPLETE INVENTORY

Consider all lighting opportunities and list the luminaires that you want to replace, and ask why you want to replace them. Is energy the only issue? If this is a retrofit, be sure to collect information on each luminaire that you want to replace (*e.g.,* lamp type(s), mounting height of luminaires, general lighting information). Please note, entrances to the parking lot and areas near the building may use different luminaire types than basic parking areas.

STEP 2: CONSIDER LIGHT QUANTITY AND QUALITY

The lighting for a parking lot is dependent upon the type of building or site that it supports as well as the surrounding area of the site. A parking lot at a national park should not have the same lighting requirements as a secure federal facility. The Illuminating Engineering Society of North America (IES) recommends light levels for basic parking lots and higher light levels for parking facilities where enhanced security is required. More light does not equal better quality. Most security cameras are rated for both very low and very high light levels, but are limited by contrast ranges. Therefore, uniform lighting will aid in viewing images on the camera as well as those physically in the parking lot.

Lighting uniformity on the pavement surface must also be considered for safe vehicle and pedestrian interaction. Too much contrast between bright and darker areas makes it more difficult to see people and vehicles in the darker areas. The use of luminaires that distribute light evenly on the parking surface and lighting layouts with appropriate spacing, are crucial to the lighting design. Consequently, one-for-one replacement may not be an option when specific light levels and uniformity ratios are targeted. Factors such as trees and other elements on the site may affect the lighting design. You can refer to IES resources or your local lighting professional for assistance. Contact the International Association of Lighting Designers and/or the IES to locate lighting professionals.

STEP 3: CONSIDER CONTROLS FOR ADDITIONAL SAVINGS

Most parking lots are lighted for 13+ hours per day; lighting controls can be used to save energy at times of infrequent use. Parking lots are often empty during certain periods at night; using controls to reduce the lighting during these periods will help save energy. Consider circuiting the luminaires on the site so certain luminaires can be either reduced in output or turned off during periods of inactivity. For example, luminaires along the perimeter could be reduced to direct users to park closer to the building during evening operation hours. Light levels can be reduced by switching off every other luminaire or selecting bi-level operation as a feature at the time of installation. To maximize energy savings potential and user satisfaction, luminaire selection, lighting controls, and installation have to be considered during the design phase and not as an afterthought.

STEP 4: SOLICIT BIDS

After selecting the right technology for your parking lot, and specifying the appropriate lighting systems and layout to deliver lighting quality and quantity, a request for proposal can be prepared. (See resources at the end of this guide for information about selecting the right technology.)

STEP 5: COST-EFFECTIVENESS

Once you have pricing and cost inputs from several sources, you can evaluate the cost-effectiveness including simple payback period, return on investment, life-cycle cost analysis, and savings-to-investment ratio. This will allow you to make the appropriate final decision. Free calculators and life-cycle cost analysis tools are offered by FEMP and by various product manufacturers and utility programs. Example cost-effectiveness calculations are provided at the end of this guide.

STEP 6: PURCHASE AND INSTALL

Clearly identify required specifications and warranties in your purchase order or contract. Most parking lot lighting systems will not require commissioning unless controls are involved. If controls are involved, be sure to identify who is responsible for commissioning before signing the purchase order. Lastly, remember to file for any utility incentives within the required period of time after project completion.

Figure 1. A pole and luminaires being removed and replaced with new equipment.

CONSTRUCTION TIP

Parking lot retrofits can be done in increments, assuming that the existing pole locations will be reused. The costs of trenching to provide power to the poles, foundation for the poles, and the poles themselves can often exceed the cost of the luminaires. If possible, reuse the pole location and even the poles to save money in a retrofit.

COMPONENTS OF THE DESIGN

There are many components that have to be considered before the design process can occur. The parking lot design coupled with the features of the luminaire (distribution, color, etc.) and how the luminaires are placed around the lot all affect the energy usage of the lighting system. Significant components of the design section include:

1. The effects of the design of the lot including materials or canopie
2. How light levels and color qualities affect the design and energy usage
3. A review of different luminaire distributions
4. Consider light spectrum for given exterior application

DESIGN CONSIDERATIONS

The energy used to light a parking lot is not only affected by the luminaire(s) selected, but also by the design of the parking lot. Factors such as materials used to construct the parking lot surface can affect lighting in the lot. Considerations made during the lighting design process addressing horizontal and vertical surfaces affect the energy usage and lighting in the lot. Additionally, solar canopies can provide on-site energy and open up new lighting opportunities, both of which save energy.

Material Selection

Although materials in a parking lot can affect the lighting, they are not always factored into the lighting or energy calculations. Many sites incorporate trees and other vegetation into the lighting design. When doing so, it is important to not only coordinate luminaire placement with the tree locations, but also to account for future growth of the tree canopy or trees. It is also important to remember that deciduous trees will have different amounts of foliage depending on the time of year. Both the foliage and the tree itself can obscure the light and potentially waste energy (see Figure 2).

Figure 2. Tree foliage can block light from luminaires.

Lighting Vertical Surfaces

Parking lot luminaires do a good job of lighting the horizontal parking surface. However, the parking surface is not visible to drivers entering the parking lot or from some parts of the parking lot. Consider lighting vertical elements—signage, architectural/sculptural pieces, solid landscape features, or the façades of the building itself. Lighting vertical elements and the façade makes the site more visually interesting, provides a destination for users of the parking lot, and makes the site feel brighter compared to sites that only light horizontal surfaces.

Solar Canopies

A growing trend in parking lots is to install solar canopies over a portion of the parking lot. A solar canopy creates covered parking for vehicles, and the top side of the canopy incorporates a photovoltaic (PV) panel. Therefore, in addition to sheltering users of the parking facility from rain and snow, the canopy can create on-site renewable energy to power parts of the adjacent buildings or even charge electric vehicles. The solar canopy also offers a lighting opportunity, providing a mounting location that is easily accessible from a ladder or a small lift (see Figure 3). Also, the lower mounting height means that a lower output (and thus lower power) luminaire is needed because the light is closer to the parking surface. As of July 2013, Tucson International Airport is in the process of installing a solar canopy to cover the parking lot in front of the main terminal. Solar canopies are not limited to the Southwest (though the climate is ideal for the canopies); they are in fact being installed across the country, including in the Northeast, and by both commercial and municipal organizations.

Figure 3. A parking lot recently retrofitted with covered parking. The covering incorporates PV panels that supply renewable energy to the site. Luminaires are mounted to the support structure for the PV panels.

LIGHTING DESIGN CONSIDERATIONS

Lighting a parking lot involves more than just using high-efficiency equipment. Multiple choices need to be made regarding the lighting and the desired results, including:

a. *Luminaire distribution* – the direction and intensity of the light leaving the luminaire. Page 9 of this document characterizes different typical distributions and how they affect the lighting design.

b. *Color qualities* – the color of the lighting and how things appear in the space matters as much as the amount and types of lighting in the space. Page 11 addresses basic color qualities of lighting.

c. *Luminaire Layout* – where the efficient equipment is placed is as important as how it is used.

d. *Desired results* – most lighting recommendations or requirements start with illuminance. This is the amount of light falling on a horizontal or vertical surface (lumens per square foot or square meter). The metric used to measure illuminance in the U.S. is the footcandle (fc), which is one lumen per square foot. The corresponding metric system unit is one lux (lx), which is one lumen per square meter. One footcandle is approximately equal to 10 lux.

The current guidance from the IES, which is referenced by most federal design requirements (including the military Unified Facilities Criteria), is RP-20-98. It is expected that RP-20 will be updated in the near future.

RP-20-98 recommends a minimum illuminance (horizontal and vertical) for different conditions in the parking lots. In addition to the minimum values, RP-20 also recommends uniformity ratios. RP-20 focuses on the ratio of maximum to minimum illuminance values and tries to limit extreme ranges of illuminance values. Table 1 provides the current IES lighting recommendations, although these may change in the next iteration of RP-20. RP-20 also provides guidelines for taking lighting measurements and what factors (*e.g.,* shadowing, light loss factors) that should be included in the calculations.

Table 1. RP-20-98 Parking Lot Illuminance Recommendations.

	Basic[1]	Enhanced Security[2]
Minimum Horizontal Illuminance	0.2 fc	0.5 fc
Uniformity Ratio, Maximum to Minimum	20:1	15:1
Minimum Vertical Illuminance	0.1 fc	0.25 fc

[1]For typical conditions. During periods of non-use, the illuminance of certain parking facilities may be turned off or reduced to conserve energy. If reduced lighting is to be used only for property security, it is desirable that the minimum horizontal illuminance value be at least 0.1 fc.

[2]If personal security or vandalism is a likely and/or severe problem, a significant increase of the Basic level may be appropriate.

RP-20-98 recommends that additional analyses of a subset of points be computed (see RP-20 for more information). In addition, for preliminary design RP-20-98 recommends an average horizontal illuminance value of 1 fc (basic) or 2.5 fc (enhanced security) be calculated. Regarding preliminary design, RP-20-98 states that a 5:1 average-to-minimum ratio is the first step toward directing the design to achieve the maximum to minimum ratios presented in Table 1. Computer software allows for computing average, maximum, and minimum values and even a specified range of values. The scenarios in this FEMP guide show the percent of calculation points between 1 and 5 fc. If the design is for average overall illuminance of 1 fc, the higher the percentage of points in the range between 1–5 fc means that this design intent is being achieved and the average is not being skewed by any extreme values. Ideally, more than 80% of the points will be in the desired range.

LUMINAIRE DISTRIBUTION

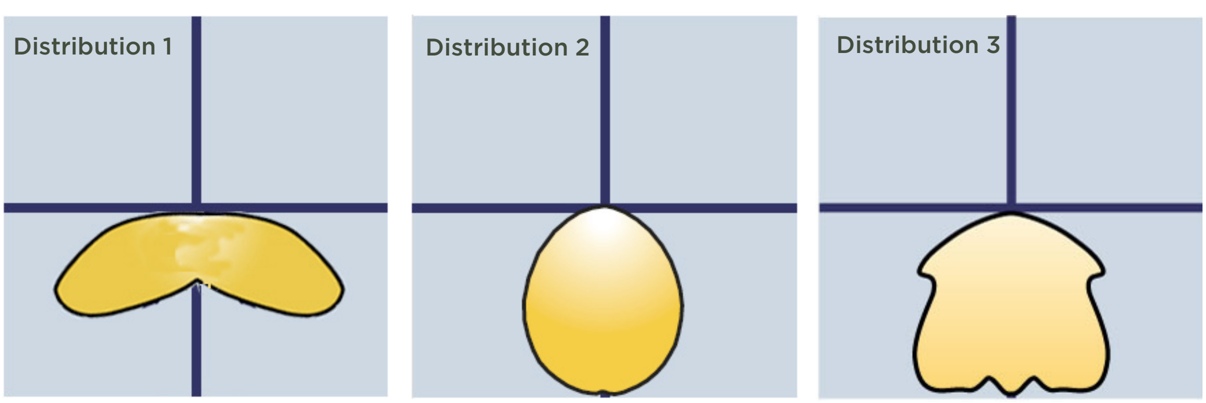
The minimum FEMP-designated luminaire efficacy rating is only one aspect of energy efficient design. Distribution can be more important than the LER of a luminaire. FEMP does not state a minimum requirement or characterize distribution because the necessary luminaire distribution is affected by the design of the space, the desired lighting results, glare control, and desired lighting aesthetics. Photometric distribution is like a building fastener—screws work in some places and rivets are better in others.

A photometric distribution illustrates how much light intensity is leaving the luminaire and in which directions. In distribution 1 – 3 (shown below), the intersection of the crosshairs is the center of the luminaire, with the bottom vertical line being below the luminaire and the top vertical line being above the luminaire. The intensity in a specific direction is proportional to the length of the ray from the crosshairs to the outline of the pattern. The following describes three typical distributions for parking lot luminaires and discusses the characteristics of each. These are *sample* distributions and should not be confused with the parking and roadway distributions known as “Type 1, Type 2, Type 3, Type 4, or Type 5” (also written as Type I, II, III, IV, or V).

Distribution 1: This distribution is sometimes called a “batwing” distribution (common in parking lots)—which means that more light is emitted at wide angles than directly below the luminaire. This allows for a wider spacing between luminaires and more uniform lighting on the ground surface.

Distribution 2: This is a “cosine distribution”—the highest intensity of distribution is directly below the luminaire. This distribution can be effective in meeting an average requirement for illuminance, but might prevent the lighting system from meeting the required or desired lighting uniformity. New manufacturers to lighting sometimes design cosine distributions. Variations of broad batwing (distribution 1) are more effective in parking lots.

Distribution 3: Manufacturers are experimenting with distribution type 3 which is somewhere between a batwing and a cosine distribution. However, because parking lot luminaires tend to be mounted 20’ or more above the ground and 100’ or more apart, wider distributions are ideal. In some applications this distribution can be effective, but it should be only used in select situations.



LUMINAIRE DISTRIBUTION

Luminaire distribution includes both general characterizations as well as the specific directions in which the light is leaving the luminaire. The previous page focused on the distribution and this page focuses on the luminaire classifications and shielding.

Cutoff

For the last 50 years, outdoor lighting has been characterized using variations of four cutoff classifications based on luminous intensity: 1. noncutoff, 2. semi-cutoff, 3. cutoff, and 4. full cutoff. Starting early in the 21st century, the lighting industry recognized the need for a classification system that focused on more than just intensity and focused on elements of the distribution in discrete ranges of angles from the luminaire. The IES officially rescinded the "cutoff" classifications and replaced them with the Luminaire Classification System (LCS)—although it is common to find various legacy cutoff requirements.

Figure 4. Even a modest shield can absorb a significant amount of the light from the luminaire and drastically reduce the luminaire efficiency.

Luminaire Classification System

The IES adopted the Luminaire Classification System in 2007 and revised the classification in 2011 (see TM-15-11 for more information). Rather than using "cutoff" terms, LCS focuses on the BUG values: backlight, uplight, and glare. The distribution of the luminaire is dissected into different categories. Each category receives a value based on the maximum lumens emitted in the different subzones. For example, a luminaire could have BUG values of B2-U0-G2.

For each application, determine what is important:

Backlight – for some applications (*e.g.*, poles in center of parking lot), the B values are less important. However, if the site is near a nature preserve, the B values of the perimeter luminaires are very important.

Uplight – only in a handful of applications does uplight provide useful light. This is light leaving the luminaire primarily above the luminaire; therefore, the light is not directed to the roadway or parking surface. However, uplight may be less of a concern in some select applications, such as urban downtown areas.

Glare – this value is very subjective , and a luminaire with a lower G value does not necessarily produce less glare than a luminaire with a higher G value. G-values correspond better to the glare perceived by the driver than the glare perceived by the pedestrian in a parking area, and therefore the G ratings have limited usefulness.

Figure 5. A floodlight had to be added to supplement the light absorbed by the shield mounted on the parking lot luminaire.

Luminaire Shielding

Shielding, often known as "house-side shields," can be installed on luminaires to block certain light leaving the luminaire to prevent light trespass and reduce glare. Figures 4 and 5 show shields of different sizes installed on sites. Both of these shields reduce overall luminaire efficiency and in both cases at least one aspect of the shield is not necessary because an adjacent area does not need to be shielded from light. The designer should anticipate where light needs to be shielded from neighboring properties, and to use internal shields designed for the luminaire for best optical control and appearance.

CORRELATED COLOR TEMPERATURE

Correlated color temperature (CCT) is used to describe the color appearance of a light source. The value is expressed in kelvins (K). A warm light source has a CCT of less than roughly 3500 K. A neutral light source has a CCT in the 3500 to 4500 K range. Cool light sources have CCTs greater than 4500 K (see Figure 6).

CCT is not a performance metric: a higher number is not better. Instead, it is a metric that describes the warmth or coolness of the light appearance. CCT is a function of light source chemistry and physics. In some cases, CCTs affect light source efficacy. For example, HPS lamps tend to have CCTs around 2100 K. There are 2800 K HPS lamps, but they are less efficacious than the 2100 K versions. Conversely, phosphor-converted LEDs are typically more efficacious when the CCT is greater than 4500 K.

Figure 6. Visual depiction of CCT values shows low CCT values are considered "warm" and high CCT values are considered "cool."

COLOR RENDERING INDEX

Color rendering index (CRI) is used to describe the color accuracy of a light source. It should be noted that CRI only describes one aspect of color. A CRI of 60 or less indicates poor color rendering, 60–70 moderate, 70–80 good, 80–90 very good, and 90+ excellent. Recent research and discussion in the lighting industry has focused on the limitations of CRI. Other metrics have been proposed, but CRI is still the default metric for color rendering in the lighting industry.

CRI is a performance metric where the higher the number, the better. Color discrimination is necessary in a parking lot to help identify clothing, faces, license plates, and vehicles. However, fine color discrimination is not necessary. For some light sources, there can be an increased cost or slight reduction in efficacy for better CRI. A CRI greater than 70 is usually sufficient for the lighting in a parking lot.

MORE INFORMATION

For more information about these color characteristics, review DOE's fact sheet on color quality. The document was produced for solid-state lighting, but the information is applicable to other technologies.

LIGHT SPECTRUM

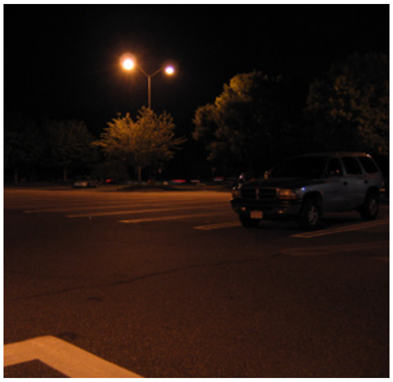


Figure 7. Narrow spectrum source lighting a parking lot.

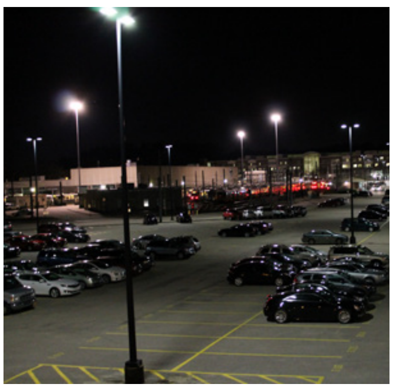


Figure 8. Broad spectrum ("white") source lighting a parking lot.

Correlated color temperature and color rendering index only describe certain aspects of the color quality and do not characterize the light source spectrum. Light sources can be grouped into either narrow spectrum or broad spectrum sources—this characterizes the amount of energy the light source emits across the visible spectrum. Narrow spectrum sources include low pressure sodium (very narrow, actually monochromatic) and high pressure sodium (narrow). Narrow spectrum sources are typically not considered "white light sources" because of the limited energy emitted by the light source (see Figure 7). Broad spectrum sources include induction, most types of LED luminaires, metal halide, and even mercury vapor. These sources are often characterized as "white" light sources because they emit energy (not in equal portions, nor continuously) across the visible spectrum (see Figure 8).

Lumens, units of light output, are calculated based on the spectrum of the light source. The lumens used to calculate the luminaire efficacy rating for the luminaires are based on photopic lumens. Photopic lumens are based on the cones (one type of photoreceptor) in the eye that are active when there is a significant amount of light (some people refer to this as "daytime" vision). There are two other visual states, scotopic (only the rods are active, extremely low light) and mesopic (rods and cones are active; between scotopic and photopic).

In recent years, research has focused on mesopic vision which is typically the operating state of the eye when a parking lot is in use at night. As a result, many different terms (some developed by marketing departments) have been used in the lighting industry to characterize light sources—these terms include: scotopic lumens, mesopic lumens, S/P ratios, pupil lumens, design lumens, lumen effectiveness multipliers, etc.

Light sources are photometered (measured) in photopic lumens. Current IES exterior recommendations are based on photopic lumens. Light spectrum can affect perceived brightness and enhance off-axis visual acuity (rods, there are no cones in the periphery of the eye). Therefore, the IES has been developing additional guidance about mesopic lighting—consult IES TM-12-12, the IES Lighting Handbook 10th edition, and the current IES recommended practices for the specific application for the latest guidance. It is also recommended to check the governing guidance for the specific federal agency regarding the type of lumens and/or spectral effects that can be factored into any lighting calculations.

In addition to using efficient equipment and utilizing an efficient design, some energy savings might be possible via factoring in light spectrum. However, the light spectrum can affect the flora and fauna near the site. Remember to consider the desired CRI and CCT if the light spectrum is going to be a key part of the energy savings strategy. Glare can be increased as well from certain elements of the visible spectrum. If the light spectrum is going to be an energy savings strategy, incorporate a lighting professional into the process and plan for a mock up in the field so that the potential new lighting can be observed before it is actually installed site wide.

PARKING LOT LIGHTING DESIGN

There is no one way to design the lighting for a parking lot. This section presents a representative parking lot with lighting designs using the same luminaire layout and spacing to show the different results from two different luminaires, one meeting the FEMP-designated requirements and another not meeting the FEMP requirements. Significant components of the following parking lot lighting design section include:

1. How color qualities and other features affect the design of the space
2. How distribution and luminaire efficacy affect the lighting values
3. How luminaire layout and efficacy affect overall energy usage

Figure 9(a). Site photo.

Figure 9(b). View from parking lot.

Figure 9(c). Luminaire.

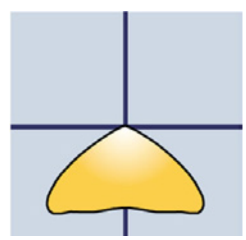
Figure 9(d). Drive aisle.

DESIGN SCENARIO OVERVIEW

The photos above depict a parking lot where two different luminaires (a general luminaire and an alternate FEMP-designated luminaire) are used. These luminaires are compared on the following pages.

Luminaire Basics:
- luminaire lumens
- input watts & LER

The distribution to the right is an example of the vertical light pattern from the existing luminaire in this parking lot. As previously stated, LER helps ensure that the luminaire is efficient, but the distribution ensures that the luminaire (and ideally the design) is effective. The following design scenarios compare luminaires with different LER values and distributions, but with the same lighting layout.



Areas with greater potential pedestrian-vehicle conflicts should have higher light levels. Examples include places where people are walking from the building to the parking lot or crosswalks in the parking lot – see photos above. Computer calculation software can render images of the space, as well as calculate the illuminance values on the parking and walking surfaces. Software can examine many metrics about lighting quantity as well as quality. The lighting information to the right is provided as sample metrics and is most applicable to parking lots.

Lighting Information:
- Average fc
- Maximum fc
- Minimum fc
- Average:Minimum
- Maximum:Minimum
- % of points 1–5 fc

Lighting power density is the metric used by most energy codes. LPD can be calculated by hand or by using simple spreadsheets, web tools, or lighting software.

Lighting Power Density:
- LPD

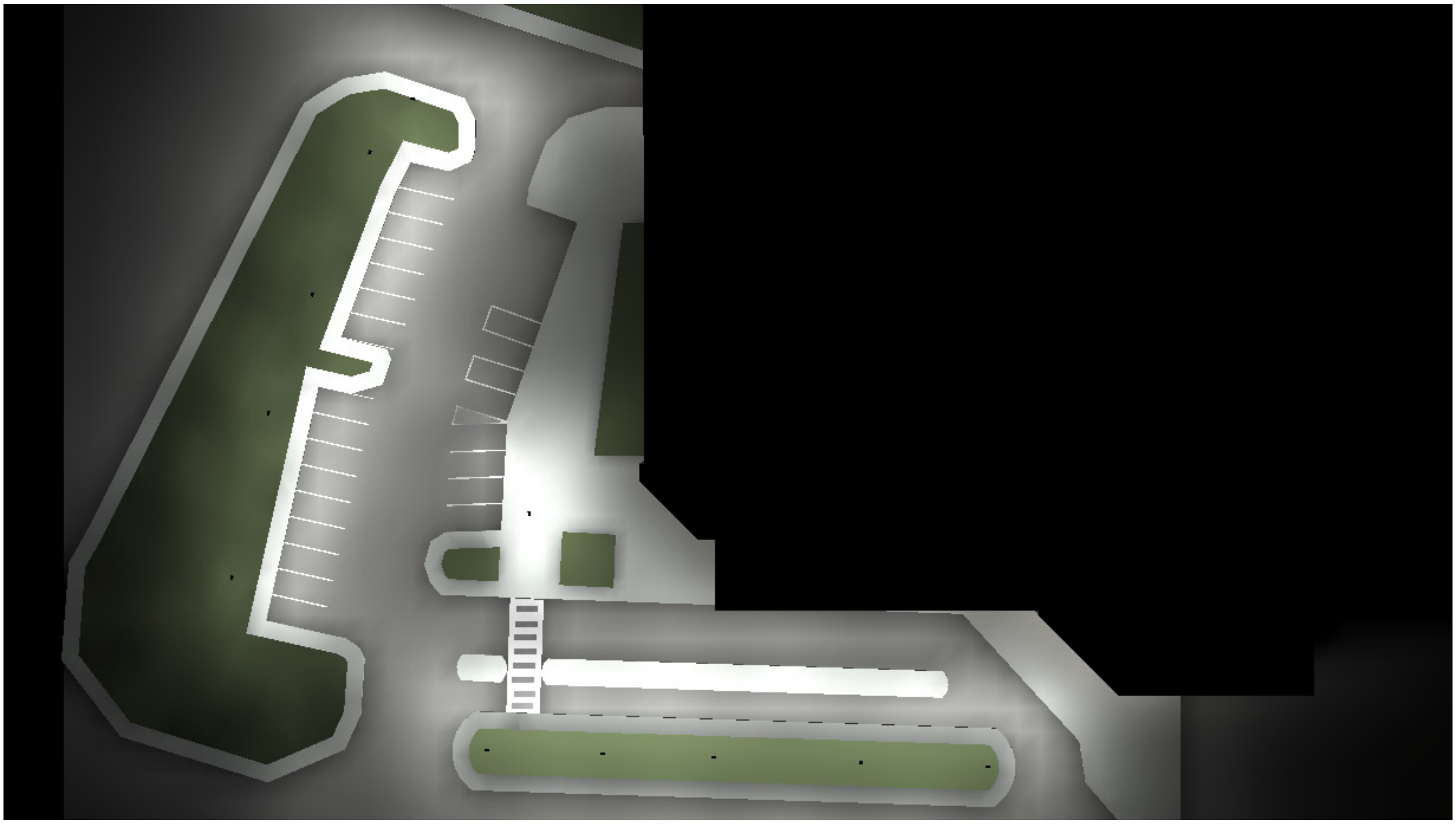


Figure 10. Plan view – (computer rendering).

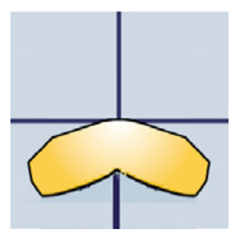
DESIGN SCENARIO – GENERAL LUMINAIRE

This general (non FEMP-designated) luminaire uses a 250 W pulse-start metal halide lamp that draws 288 W together with the ballast. The CCT is in the 3500–4500 K range, with a CRI in the 70s. The LER is 51 lm/W.

Luminaire Basics:

- 14,725 luminaire lumens
- 288 W input watts – LER: 51

The light distribution plot shows that the luminaire produces a batwing pattern. The commonly used batwing distribution is common in parking lot luminaires.



The design with this luminaire meets the minimum illuminance of the RP-20-98 recommendation, but the average illuminance is high. Calculated metrics for uniformity (maximum:minimum) exceed the RP-20-98 recommendation of 20:1. However, the portion of points calculated between 1–5 fc is 76%, which means the uniformity is only fair (compared to good or great). Calculations represent the initial values and do not include light loss factors (LLF). LLF should be included and determined by the site.

Lighting Information:

- Average: 7.4 fc
- Maximum: 10.5 fc
- Minimum: 0.3 fc
- Average:Minimum: 12:1
- Maximum:Minimum: 35:1
- % of points 1–5 fc: 76%

The calculated LPD for this design is lower than what some energy codes prescribe. LPDs between 0.10–0.15 W per square foot (W/sf) are common for existing installations and as well as many new installations.

Lighting Power Density:

- LPD: 0.13 W/sf

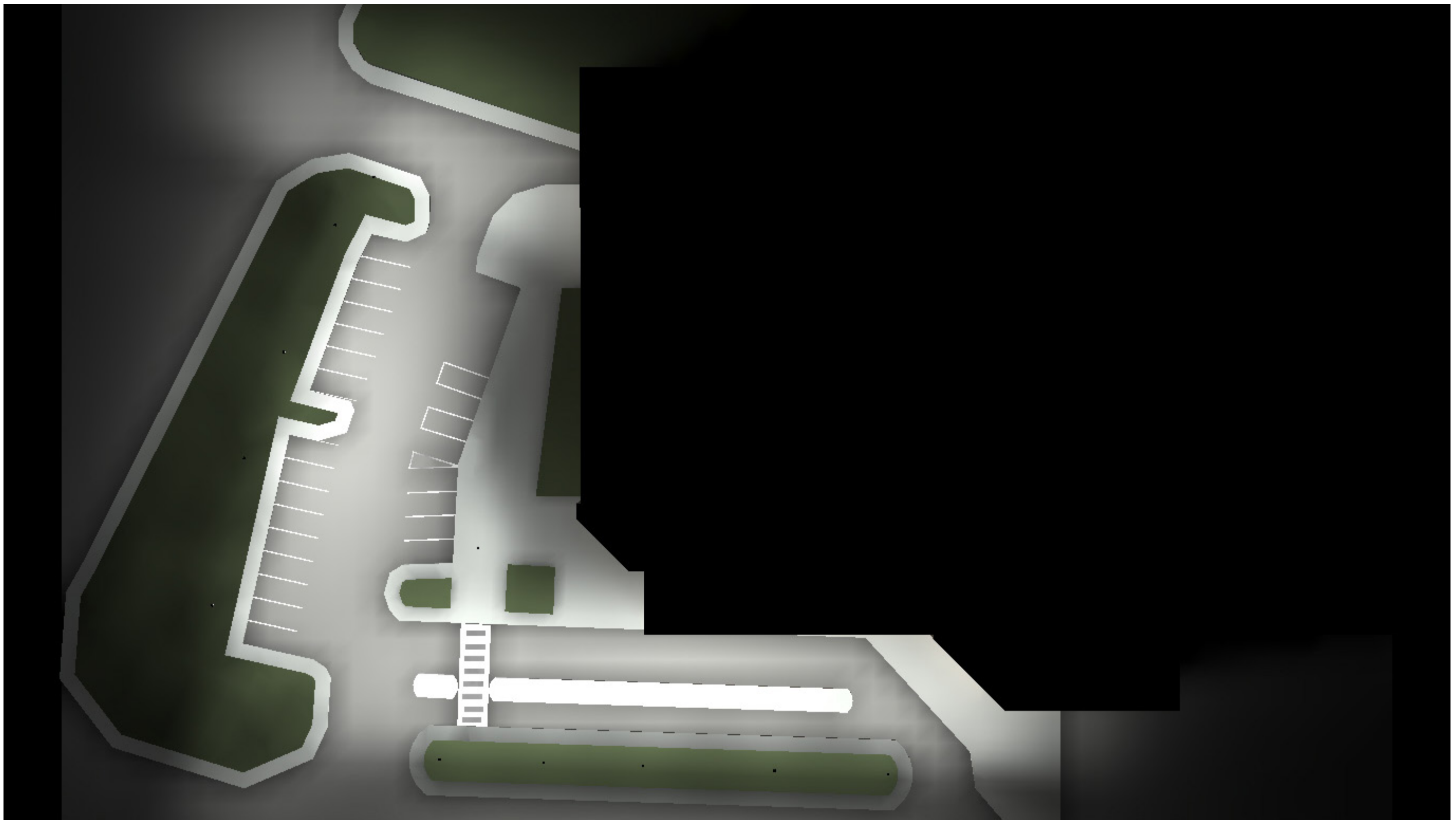


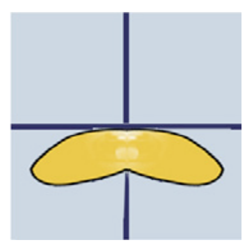
Figure 11. Plan view – (computer rendering).

DESIGN SCENARIO – FEMP-DESIGNATED LUMINAIRE

The FEMP-designated luminaire has color qualities of 4000 CCT and a CRI in the 70s. The LER is 73 lm/W. It should be noted that this luminaire emits 27% fewer lumen than the general (non FEMP-designated) luminaire in this example.

Luminaire Basics:
- 10,758 luminaire lumens
- 147 W input watts – LER: 73

This distribution for this luminaire does not emit any uplight, and is slightly wider than the general luminaire example. The lower lumen output of 10,758 lumens leads to lower illuminance values, and the slightly wider distribution leads to better uniformity.



This design has a similar minimum illuminance value as the general luminaire design. This design does meet the RP-20 maximum/minimum uniformity requirement of 20:1. In addition, this design has more calculated measurement points in the range between 1–5 fc. LER is an important characteristic, but make sure that the luminaire provides sufficient lumens to meet the targeted light levels. Calculations represent the initial values and do not include LLF. LLF should be included and determined per site.

Lighting Information:
- Average: 3.4 fc
- Maximum: 5.6 fc
- Minimum: 0.4 fc
- Average:Minimum: 9:1
- Maximum:Minimum: 14:1
- % of points 1–5 fc: 95%

The LER is roughly 43% higher than the LER for the general luminaire design. However, the LPD is 46% lower because the selected distribution allows for a luminaire optimization, saving additional energy while providing a suitable amount of lighting and quality.

Lighting Power Density:
- LPD: 0.07 W/sf

LIGHTING CONTROLS SAVE ENERGY

Installing energy efficient equipment is one step towards an energy efficient design – a good compliment are lighting controls. Energy is power multiplied by time; controls can either reduce the time or power components of the equation. Ideally it is best to install controls at the same time as installing any new or replacement equipment because the electrician is already on site. Controls are emerging in parking lots because of new technologies that can yield significant energy savings on top of the efficient luminaires. Significant components of the following lighting controls section include:

1. Types of controls that can be used in parking lots
2. Factors to consider when selecting lighting controls for parking lot
3. Recommendations to maximize energy savings

STATIC CONTROLS

Currently, most parking lot lighting controls are static. The controls turn on the luminaires—the luminaires operate at one output level and then turn off. Typical static lighting controls consist of photocells and astronomical timeclocks or combinations of the two controls.

Photosensor

Photosensors include the entire control device including the housing, the optics, electronics and the photocell. In exterior applications, the photosensor is typically mounted to the luminaire or in some cases close to a small group of luminaires. The sensor detects insufficient or sufficient daylight and turns the luminaire on or off respectively.

Figure 12. "Dayburners" operating in the middle of the day.

One of the disadvantages of this control technology is that climatic changes (*e.g.*, significant cloud cover or snow) can create a false positive and trigger the photosensor to turn on the luminaire during the day, even when there is sufficient daylight. This is a condition known as "day burning" which wastes energy (see Figure 12 for an example). Day burning can also be a result of the materials in the photocell itself. The materials in the photocell can change over time and become less sensitive meaning that the photosensor turns on the luminaire earlier in the evening and off later in the morning.

Another disadvantage of photosenors is that the devices can have a short life compared to the luminaire. If using this control device, specify a high-life photosensor so that any monetary savings generated by installing a low maintenance luminaire are not negated by having to replace the photosensor.

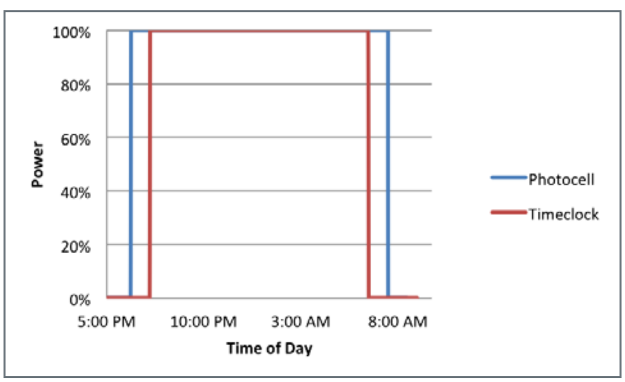


Figure 13. Comparison of operation of luminaires via photocell and timeclock.

Astronomical Timeclocks

An astronomical timeclock can adjust the on and off times of the luminaire with the change in seasons and for daylight savings time. The advantage of timeclocks is that dayburning does not occur because timeclocks are not affected by the available daylight. Furthermore, timeclocks can more precisely control both turn on and off operation. In some cases, time-based savings can be 15% or more than with a simple photosensor. Figure 13 compares the on/off times of a luminaire controlled by a timeclock with those of a luminaire controlled by a photosensor.

MULTI-LEVEL CONTROLS

Rather than turning on the luminaires at sunset and turning them off at dawn, multi-level (typically bi-level; two output levels) controls can be used—meaning that the lighting can be in different operating states in the middle of the night.

When selecting bi-level operation, the low output setting needs to be determined. Typically, lighting designs (justifiably) provide more light than is required when the parking lot is expected to be occupied. In the low output setting, the luminaire output can be set to what is just absolutely necessary. Figure 14 shows a multi-level operation where the luminaire is only reducing the power by one-third. This example is a 30% energy savings compared to photosensor-only operation. Figure 15 shows a multi-level operation where the luminaire is reducing the power by two-thirds. In this example, the savings are 44% compared to the photosensor operation.

Fixed Response

Through timeclocks (and even a combination photosensor and timeclock), the lighting can be reduced during a predetermined period in the night. The reduction can be achieved via two methods: selective switching of the luminaires or bi-level operation of the luminaires. In selective switching, every other or specific luminaires are turned off while the others remain operating. This can be an effective strategy, but requires careful coordination in the design and selection of the luminaires that will remain operating.

Bi-level operation is another option in which a certain amount of luminaire output is reduced at a predetermined time. This strategy allows the lighting coverage to remain the same; however, it reduces energy savings. This strategy requires a lighting technology that allows for bi-level operation and either additional wiring or a control signal to direct the luminaire to the low output setting.

Dynamic Response

Occupancy sensors, a proven interior lighting control, are now being developed for parking lot applications. This is an emerging lighting control technology that has promise, once the remaining technological hurdles are addressed. The advantage of a dynamic response is that it allows for more energy savings compared with turning to low operation at a certain time. Figure 16 is an example of the output of a parking lot luminaire controlled by an occupancy sensor. The luminaire goes into the low setting (in this case 50% power reduction) and only increases when stragglers from the building or security patrols enter the parking lot.

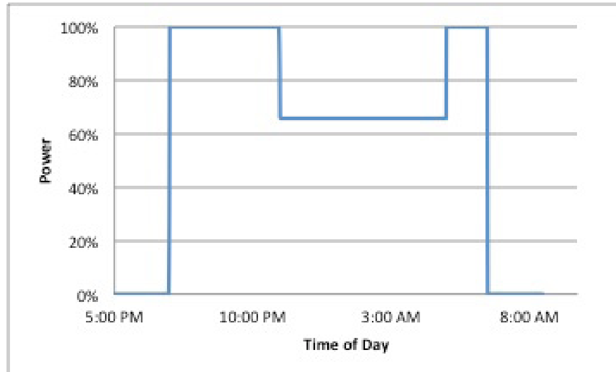


Figure 14. Bi-level operation with static power reduction of 33% in low setting.

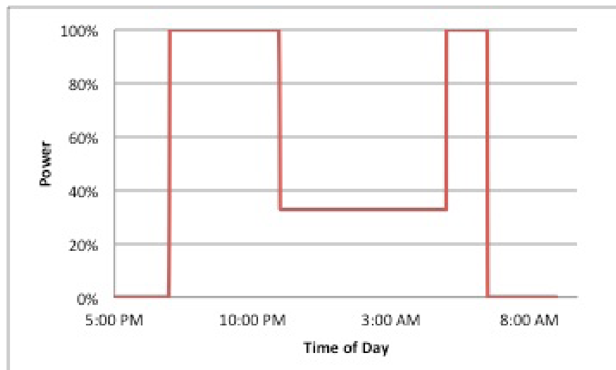


Figure 15. Bi-level operation with static power reduction of 66% in low setting.

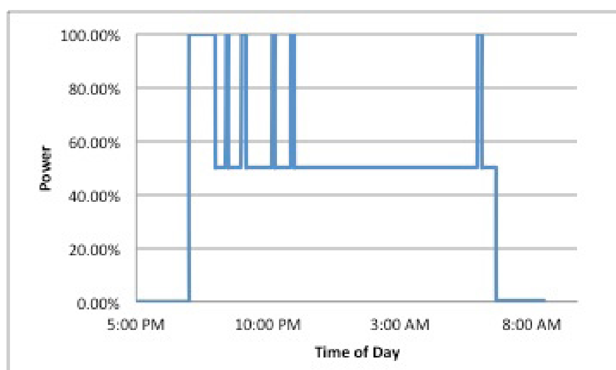


Figure 16. Bi-level operation via occupancy sensors with power reduction of 50% in low setting.

COST-EFFECTIVENESS

An efficient product option is cost-effective relative to a base model when the cost savings (energy and maintenance) exceed any incremental costs, including installation over a comparable functional lifetime. Federal purchasers may assume that products meeting FEMP-designated efficiency requirements are life-cycle cost-effective if the net savings are positive. An example is provided in Table 2, comparing a base model to a luminaire that meets the FEMP requirements. Here, because the luminaire meeting the FEMP requirement's first cost (lamp cost + luminaire price) is less than the "Lifetime Operational Cost Savings" from Table 2, the product is cost-effective. Users wishing to determine cost-effectiveness for their applications may do so using the example provided in Table 2.

Products meeting FEMP-designated efficiency requirements may not be life-cycle cost-effective when energy rates are below the federal average or in certain low-use applications. For most applications, purchasers will find that energy-efficient products have the lowest life-cycle cost. In high-use applications or when energy rates are above the federal average, purchasers may save more if they specify products that exceed the federal minimum efficiency requirements. Table 2 is an example, and values will vary by site.

Table 2. Lifetime Savings for Efficient Parking Lot Luminaires

Cost-Effectiveness Example		
Performance	**Base Model**	**Required Level (*minimum LER 65*)**
	Pulse-Start Metal Fixture	**LED Fixture**
Luminaire Efficacy Rating (LER)	62	73
Luminaire Output	14,725 lumens	10,758 lumens
Power Input	288 watts	147 watts
Light Source Life[1]	15,000 hours	100,000 hours
Lamp Cost[2] (a)	$54	---
Luminaire Price[2] (b)	$396	$1,448
Annual Energy Use[3] (c)	1,261 kWh	644 kWh
Annual Energy Cost[4] (d)	$128	$65
Lifetime Energy Cost[5] (e)	$2,020	$1031
Lifetime Replacement Cost – Lamp (f = a x 6.8[6])	$221	–
Lifetime Replacement Cost – Labor[7] (g)	$266	–
Total Lifetime Costs[8] (b+e+f+g)	$2,903	$2,478[9]
Lifetime Cost Savings (Base Model – Required Level)	**–**	**$425**
Lifetime Operational Costs Savings [Base (e+f+g) – Required (e+f+g)]		**$1,118**

[1] Life value is per manufacturer's data. LED luminaire life encompasses many elements, but this manufacturer claims 100,000 hours for the LEDs (L87).

[2] Prices for real products from www.gsaadvantage.com (last accessed April 15, 2013).

[3] Assumes 12 hour x 365 day operation and does not assume the use of lighting controls.

[4] Assumes an electricity rate of $0.10/kWh; substitute your rate as required. Future electricity price are based on federal guidelines and forecasts effective from April 2012 to March 2013.

[5] For this analysis, the lifetime is 23 years. This was calculated by dividing the longest life system (100,000 hours) by 4,380 (12 hours x 365 days).

[6] Discount rates are the reasons this value does not equal $54 x 6.8

[7] Assumes an electrical worker spending a set amount of time to replace the lamps in the luminaire. In this case, labor is the sum of the discounted value of the labor and associated equipment costs (*e.g.*, truck lift) to replace a lamp. The assumed labor cost is $65 per hour. Substitute with your data as required.

[8] A real discount rate of 3.0% is based on federal guidelines effective from April 2012 to March 2013.

[9] Discount rate and future costs are the reasons this value does not equal $1,448 + $1,031.

RESOURCES

The following are resources from the U.S. Department of Energy (or supported by DOE) that specifically focus on parking lots. DOE also offers general and specific information about lighting.

Lighting, Development, Adoption, and Compliance Guide

This 2012 guide, starting on page 24, provides guidance on complying with energy codes for parking lots and includes important information on lighting controls.

http://www.energycodes.gov/sites/default/files/documents/Lighting_Resource_Guide.pdf

Use of Occupancy Sensors in LED Parking Lot and Garage Applications: Early Experiences

Occupancy sensors in parking lots are an emerging controls option, but are gaining interest. This 2012 report from the DOE GATEWAY Program highlights both the success and challenges experienced with occupancy sensors in these environments.

http://apps1.eere.energy.gov/buildings/publications/pdfs/ssl/2012_gateway_sensors.pdf

Exterior Lighting Guide for Federal Agencies

This 2010 guide for federal agencies provides tips for evaluating light sources, performing lighting audits, and pairing lamps with lighting controls. It focuses on exterior applications.

http://cltc.ucdavis.edu/images/documents/publications_reports/DOE_FEMP_Exterior_Lighting_Guide.pdf

LED Provides Effective and Efficient Parking Area Lighting at the NAVFAC Engineering Service Center

This 2010 case study of an LED demonstration resulted in 74% energy savings compared to the existing HPS system. Uniformity was greatly improved with LED luminaires compared to the existing high pressure sodium luminaires. The case study discusses spectral effects – see "nighttime illuminance" in the case study which provides additional context to the spectral effects discussion in this guide.

http://www1.eere.energy.gov/femp/pdfs/etcs_ledparking.pdf

CBEA LED Site Lighting Specification

This LED site lighting performance specification is intended to provide adequate illumination in parking lots, and save energy by reducing the installed power density of equipment below code as well as using controls to further reduce energy use.
http://apps1.eere.energy.gov/buildings/publications/pdfs/alliances/cbea_led_site_lighting_spec.pdf

The Department of Energy's Federal Energy Management Program's (FEMP) mission is to facilitate the Federal government's implementation of sound, cost-effective energy management and investment practices to enhance the nation's energy security and environmental stewardship.

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