

# THE LIGHTING FIELD GUIDE

UPGRADING TO LEDs  
FOR MULTI-FAMILY HOUSING

**ASSIST**

Alliance for Solid-State Illumination  
Systems and Technologies

Lighting  
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Please note that references to external organizations within *The Lighting Field Guide* do not imply endorsement, recommendation, or favoring of those programs. Any data gathered from external organizations is solely the responsibility of that organization. It is the responsibility of the end user or purchaser to verify performance claims made regarding a particular product.

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# The Lighting Field Guide: An Overview

More than half of renters live in multi-family housing. These buildings have a range of lighting technologies in use, most typically fluorescent and incandescent (indoors) and high pressure sodium or metal halide (outdoors). An attractive means of controlling costs for a building is through energy-saving measures. In March 2012, the United States Department of Housing and Urban Development invested \$23 million in researching methods, strategies, and technologies that could reduce the energy consumption (and in turn, the carbon foot-

print) of multi-family and affordable housing sites<sup>1</sup>. One method to reduce energy consumption using available technology is to replace existing lighting with LED lamps and fixtures. *The Lighting Field Guide* is designed to help managers, operators, and maintenance staff of multi-family and affordable housing to choose better quality LED products that are appropriate for their site as a way of reducing energy use and lowering lamp replacement and maintenance costs while maintaining a well-lighted environment.

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## LED Lighting Overview

LED technology has matured to a point where it is now becoming the light source of choice for many illumination applications. LED light sources have several advantages when compared with traditional light sources, including incandescent, halogen, high intensity discharge (HID), and fluorescent lamps. In many cases, LED products are able to reduce energy consumption and lower replacement costs due to long service life.

LEDs are suitable for many indoor and outdoor applications, and can often be used with different types of lighting controls for extra energy savings. LED products can be dimmed or switched on and off without sacrificing lamp life, while compact and linear fluorescent lamps and HID cannot be easily dimmed or switched frequently without negatively impacting lamp life. Therefore, it is more difficult to reap benefits using lighting controls technologies that employ frequent switching with compact and linear fluorescent lamps or HID lamp luminaires.

Of all the light source technologies used in indoor

and outdoor applications, it is the performance and life-cycle cost of linear fluorescent lamps that is difficult to match with present-day LEDs, with the exception of a very few products. Even though LEDs are expected to reduce in price in the next few years, today they have a higher initial cost compared with most traditional light source technologies. However, because LED light sources can save energy and reduce maintenance cost, many electric utilities, state, and federal agencies have introduced rebate programs that can buy down the initial cost, thus making them cost effective.

It is important to note that not all LED lighting products are created equal. The following section outlines the most important metrics to look for when selecting an LED lighting product, regardless of the type of room or space to be lighted. Usually these metrics are shown or listed on the LED product packaging. If you are buying new lighting fixtures, this information is available from the manufacturer or dealer representative, or on the fixture's specification sheet.

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<sup>1</sup>U.S. HUD. 2012. HUD awards \$23 million to test new energy-saving approaches in older multi-family housing developments. 12(051), 1-11. Accessed February 6, 2013 from [http://portal.hud.gov/hudportal/HUD?src=/press/press\\_releases\\_media\\_advisories/2012/HUDNo.12-051](http://portal.hud.gov/hudportal/HUD?src=/press/press_releases_media_advisories/2012/HUDNo.12-051).

# Metrics to Consider When Selecting LED Lighting

There are many LED lighting products on the market today that can meet the requirements of multi-family and affordable housing; however, not all LED lighting products are created the same. Performance is key to the success of any lighting technology. Prior to selecting an LED lighting product, it is important to research a product's performance on websites such as ENERGY STAR® ([energystar.gov](http://energystar.gov)) and Lighting Facts® ([lightingfacts.com](http://lightingfacts.com)).

## 1 Luminous flux (lumens)

When upgrading to LED lighting, matching the lamp or fixture lumens of the existing lighting often yields good results. Lamp lumens can be used to compare replacement lamps. Fixture lumens are the total amount of light leaving the fixture (taking into account

losses from the housing, optics, and ballast/driver) and are used to compare two fixtures in terms of light output. If the space seems dark or if elderly residents

*Make and model are typically printed on a lamp.*

live in this housing, an increase in lumens will be beneficial.

To find the lumen output of existing lighting, look for the make and model of the existing lamp (information is often printed on the lamp itself). Using this information, a quick Internet search should provide lumen output data.

## 2 Efficacy

Efficacy indicates how efficiently a light fixture or lamp converts electric power into light and is described as lumens per watt. This can be calculated by dividing the lumen output by the wattage. Unlike traditional lighting, LED lighting can be delivered as either a screw-base lamp or as a full fixture (lamp, optics, electrical drivers, etc.). Look for an efficacy of at least 50 lm/W when selecting an LED product.

## 3 CCT

CCT refers to the color appearance of white light and is measured in kelvin (K). Lamps with CCTs in the range of 2700 K to 3500 K are considered warm

The most common performance metrics used to describe a light source or lighting system include luminous flux (lumens), luminous efficacy (lumens per watt, lm/W), color appearance (correlated color temperature [CCT, in kelvin]), color rendering (color rendering index, CRI), life (in hours), and lumen maintenance (rate of decrease in light output over time).

white, while 3500 K – 4100 K is typically considered neutral white. Any CCT higher than 4100 K is considered cool white. Incandescent lamps typically measure at about 2700 K. To maintain aesthetics, it is advisable to use similar correlated color temperature sources, especially in the same room. The preference for CCT can vary amongst people. In general, in North America, warmer lights are typically used in residential spaces.

## 4 CRI

When lighting areas where people are doing tasks that require identifying colors such as cooking or choosing clothing, it can be beneficial to have lighting with high CRI (80 or higher). Typically, a high CRI is also preferred for security areas where identifying colors at night may be important.

## 5 Rated Lifetime

The rated life indicates how many hours or years it will be before the lamp or fixture needs to be replaced. Conventional lighting technologies like incandescent lamps fail by breaking (e.g., the filament), and therefore fail to produce any light. However, most LED replacement lamps and fixtures will degrade in light output slowly over time and eventually come to a point where there is not enough light by which to see. The LED lighting industry typically defines the end of useful life as the point at which the light output reaches 70% of its initial value — known as L70. This is a common replacement time frame.

Before selecting an LED product, look at the specification sheet for the rated L70 value. The L70 value should be greater than 50,000 hours for fully integrated LED fixtures, and at least 25,000 hours for LED replacement lamps.

## Warranty

Look for a 5-year minimum product warranty. Most manufacturers claim their lamps to have a useful life of 25,000 hours (2.8 years at 24 hours per day) and their fixtures to have a useful life of 50,000 hours (5.7 years at

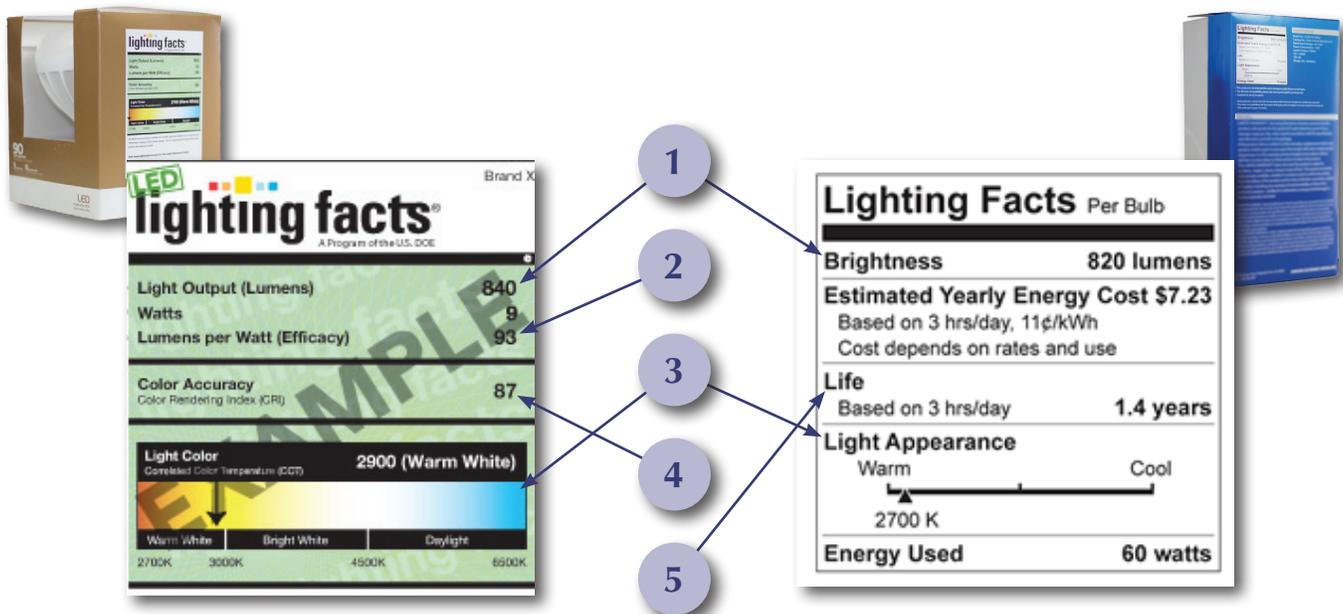
24 hours per day). Examine the warranty terms carefully and make sure to keep any packaging required in case the product fails within the warranty period.

## The Facts about Lighting Labels

The U. S. Department of Energy (U.S. DOE) produces a Lighting Facts® label for LED lighting products that lists the light output (lumens), watts, lumens per watt (efficacy), light color (CCT), and color accuracy (CRI). Optionally, the percentage of initial light output after 25,000 hours and warranty availability may also be listed (not shown). The label can often be found in product literature and on product packaging for LED lighting other than medium screw-base lamps. ENERGY STAR® now requires all qualified products to carry this

label; however, this program is voluntary for products that are not ENERGY STAR qualified, so not every LED product will have this label.

Another lighting label, issued by the Federal Trade Commission (FTC), is also called Lighting Facts. This label is mandatory for all screw-base lamps, regardless of technology. This label gives the brightness (lumens), estimated yearly energy cost, lifetime estimate, light appearance (CCT), and energy used (watts). This label is convenient for comparing different lamps in stores.



*U. S. DOE Lighting Facts label—  
found on ENERGY STAR lamps and  
fixtures if FTC label is not used*

*FTC Lighting Facts label—  
found on all medium screw-base lamps*



## ENERGY STAR® Qualified Products

When choosing LED lighting, look for ENERGY STAR qualified products. These can be found on lists published by ENERGY STAR ([energystar.gov](http://energystar.gov)). Qualified products have been tested for lifetime, light output, and color consistency. These products may also be candidates for rebates and incentives (see below).

## Incentives

There may be incentives and rebates available to switch to energy-efficient fixtures and lamps, as well as manufacturer rebates for purchasing LED fixtures. Certain programs also offer incentives for using qualified products, such as those listed with ENERGY STAR ([energystar.gov](http://energystar.gov)), U.S. DOE Lighting Facts ([lightingfacts.com](http://lightingfacts.com)), or DesignLights Consortium® ([designlights.org](http://designlights.org)), to

name a few. One comprehensive resource for finding state and federal incentives is DSIRE™ ([dsireusa.org](http://dsireusa.org)), which is a database of current incentives available that could assist in offsetting the initial cost of a lighting project. In addition, check with local energy companies to find out if they offer any rebates or assistance when switching to LED lighting.

## Environmental Considerations

Another benefit of reducing energy consumption, beyond cost savings, is a reduction in greenhouse gas emissions. This reduction in greenhouse gas emissions, or carbon footprint, can contribute to reducing the impact electricity use has on our environment. In addition to the incentives and rebates discussed above, there may also be additional incentives from environmental organizations for offsetting greenhouse gas emissions.

In order to calculate your greenhouse gas emissions offset, you need to be able to calculate your current annual electricity use (before upgrading your lighting system) and your projected annual electricity use (after upgrading your lighting system). The following formula includes the values needed to calculate the amount of CO<sub>2</sub> saved from upgrading your lighting system:

$$\text{carbon dioxide saved: } \frac{(\text{current electricity use} - \text{projected electricity use}) \times 1,301.31 \text{ lbs. CO}_2 \text{ per kWh}}{1,000 \text{ kWh} \times 2,204.6 \text{ lbs.}}$$

For more information on calculating carbon dioxide and other greenhouse gas emissions, visit the U.S. EPA's website at [www.epa.gov/cleanenergy/energy-resources/calculator.html](http://www.epa.gov/cleanenergy/energy-resources/calculator.html).



# Application Notes

## Operating Temperature

LED products will often specify a range of temperatures within which to operate the lamp. Be sure this range covers the desired installation environment. Specifically, some LED replacement lamps state that they are not to be used in enclosed fixtures, while other lamps are designed for enclosed fixtures. Some recessed LED fixtures are rated for direct contact with insulation in ceilings or use in wet locations, while others are not. Operating an LED product in an environment where the temperature is above the rated product temperature can reduce the overall lifetime of that product.

## Measuring Light Depreciation

The light output of LED lighting fixtures depreciates over time. In some applications, it is important to keep track of the light level in the space to ensure it remains within code and standard requirements. A photo detector called an illuminance meter is used to measure light level. Performing illuminance measurements at least once a year will let you know if the fixtures are producing light levels that meet regulation, as well as give you an indication if the lamps need to be replaced. Refer to the user manual of the illuminance meter for measurement instructions.

## Weight

Many LED replacement lamps and fixtures can be heavier than their incandescent or fluorescent counterparts. Make sure the installation location, including the

inside of a fixture, can accommodate the extra weight of the LED lamp.

## Delayed Start Time

LED lamps and fixtures require a driver to operate properly. When an LED product is switched on, this driver may take 1 - 2 seconds to start, delaying the initial output of the lighting device. The LED product, once on, will come to full output immediately. This delay in start up is normal for LED devices.

## Dimmer Compatibility

Many LED products are dimmable. However, there is a wide variety of dimming performance among products. Different products can have different dimming characteristics such as flicker and audible noise that can be markedly different from incandescent lamps.

The best option is to use compatibility tables provided by the dimmer manufacturers and lamp or fixture manufacturers. These tables can be accessed online before purchasing the products. Selecting dimmer and LED products that are listed as being compatible improves, but does not fully insure, the likelihood of system compatibility. (Finding a product that is compatible with an existing dimmer may be more difficult). If possible, test out the combinations of LED products and dimmers under consideration to ensure functionality before making a full commitment.

# Purchasing LED Products

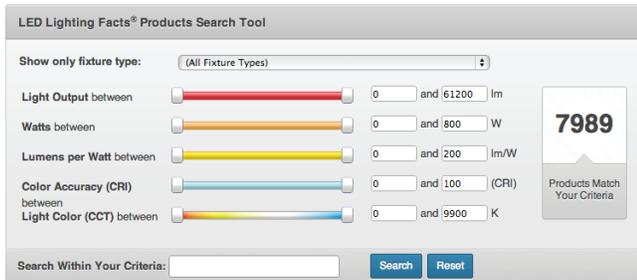
Since LED lighting products are relatively new to the lighting market, not all types of LED lamps and fixtures are available at every store. LED A-lamps and BR/PAR replacement lamps can usually be found at big box home improvement stores and large retail chains. These stores may also offer integrated LED fixtures, however the selection of these fixtures may be limited.

Linear LED lamps (for replacing T5, T8, and T12 linear fluorescent lamps) and integrated LED fixtures are usually sold online, either from a lighting website or, less often, directly from a manufacturer. Often the best way to get accurate information for LED products is through the U.S. DOE Lighting Facts® website (lightingfacts.com) or the ENERGY STAR® website (energystar.gov).

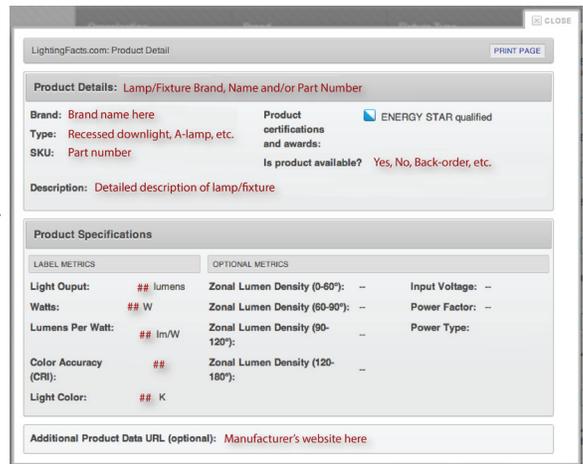
The information on the website (as well as a manufacturer website) will be the same as the label on the product packaging. In addition, the product model number will be listed (so you can specify what you are looking for), often with the website for the manufacturer. If a manufacturer does not sell a specific product directly, they will often be able to assist in finding a local sales representative.

Lighting sales representatives often work with a variety of manufacturers, and should be able to provide pricing information for products as well as the performance metrics of the lamps or fixtures being sold. However, not all sales reps work with all manufacturers, so contacting more than one sales representative may be necessary.

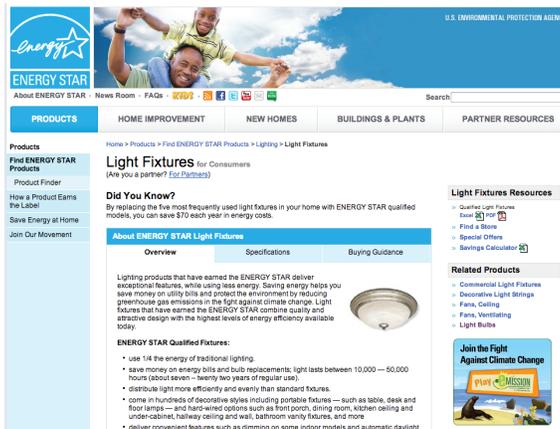
*U.S. DOE Lighting Facts website. Select fixture (or lamp) type, then narrow the search by limiting the light output (lumens), watts, lumens per watt (efficacy), color accuracy (CRI), and light color (CCT).*



*Clicking on a product will show specific information, often including a manufacturer website. Contacting a manufacturer can help identify purchasing options.*



*The ENERGY STAR website offers lists of qualified lamps and fixtures, available for download.*



# Savings Calculations

LED products have the potential to offer considerable energy savings. Below is a table illustrating the cost

savings available by reducing energy. These savings are calculated using the following simple formula:

$$\text{annual savings(\$)} = \frac{(\text{use per day [hours]} \times \text{reduction in power [W]})}{1000 \times \text{energy cost (\$/kWh)} \times 365 \text{ (days per year)}}$$

W = watts; kWh = kilowatt hours; \$ = U. S. dollars

## Annual savings based on power reduction and use

	Hours per Day of Use						
	1	2	3	4	6	12	24
5	\$0	\$0	\$0	\$1	\$1	\$3	\$6
10	\$0	\$1	\$1	\$2	\$3	\$6	\$13
20	\$1	\$2	\$3	\$4	\$6	\$13	\$26
30	\$1	\$3	\$4	\$6	\$9	\$19	\$39
40	\$2	\$4	\$6	\$8	\$13	\$26	\$52
50	\$2	\$5	\$8	\$10	\$16	\$32	\$65
60	\$3	\$6	\$9	\$13	\$19	\$39	\$78
70	\$3	\$7	\$11	\$15	\$22	\$45	\$91
80	\$4	\$8	\$13	\$17	\$26	\$52	\$105
90	\$4	\$9	\$14	\$19	\$29	\$59	\$118
100	\$5	\$10	\$16	\$21	\$32	\$65	\$131

### Assumptions

- Savings assume \$0.15 per kWh
- Assumed energy cost includes generation and delivery
- Savings does not account for potential savings from reduced demand charges, if applicable

### Typical Hours per Day of Use (by location)

- Kitchen ..... 4
- Bathroom..... 2
- Hallway ..... 24 (see local codes)
- Lobby ..... 24 (see local codes)
- Common room..... Varies

# Payback Calculations

The simple payback on a given project will depend on the initial cost of the LED lamp or fixture being purchased and the total savings accrued from energy

reduction over the lifetime of that lamp or fixture. Simple payback can be calculated using the formula below. The table below shows some generic payback scenarios.

$$\text{payback (in years)} = \frac{\text{new lamp or fixture cost}}{\text{annual energy cost savings per year (page 10)}}$$

## Payback for a lighting product(s) based on initial cost and savings per year

Initial Fixture Cost	Energy Cost Savings per Year												
	\$5	\$10	\$20	\$30	\$40	\$50	\$60	\$70	\$80	\$90	\$100	\$125	\$150
\$5	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
\$10	2	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
\$15	3	2	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
\$20	4	2	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
\$25	5	3	1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
\$50	10	5	3	2	1	1	<1	<1	<1	<1	<1	<1	<1
\$100	20	10	5	3	3	2	2	1	1	1	1	<1	<1
\$150	30	15	8	5	4	3	3	2	2	2	2	1	1
\$200	40	20	10	7	5	4	3	3	3	2	2	2	1
\$250	50	25	13	8	6	5	4	4	3	3	3	2	2
\$300	60	30	15	10	8	6	5	4	4	3	3	2	2
\$350	70	35	18	12	9	7	6	5	4	4	4	3	2
\$400	80	40	20	13	10	8	7	5	5	4	4	3	3
\$450	90	45	23	15	11	9	8	6	6	5	5	4	3
\$500	100	50	25	17	13	10	8	7	6	6	5	4	3

• Years shown in the chart have been rounded to the nearest year

These payback values do not take into account savings that may be derived from reduced maintenance costs. Additionally, the initial fixture cost does not include any discounts and/or rebates that may be available from state agencies or power utilities, which can reduce the initial investment for a lighting project.

Below is a table for converting the listed lifetime of a lamp or fixture (usually given in hours) to the lifetime in

years based on how many hours per day the lamp or fixture is used. The payback period for any lighting product should not exceed the lifetime of the product based on its intended use.

For example, if an LED fixture having a rated lifetime of 50,000 hours and is typically used 12 hours per day, 7 days per week, then the payback should be no more than 11.4 years.

## Lifetime of a lighting product based on rated lifetime and use

Rated Lifetime (hours)	Hours per Day of Use						
	1	2	3	4	6	12	24
1000	2.7	1.4	0.9	0.7	0.5	0.2	0.1
2000	5.5	2.7	1.8	1.4	0.9	0.5	0.2
5000	13.7	6.8	4.6	3.4	2.3	1.1	0.6
10000	27.4	13.7	9.1	6.8	4.6	2.3	1.1
20000	54.8	27.4	18.3	13.7	9.1	4.6	2.3
25000	68.5	34.2	22.8	17.1	11.4	5.7	2.9
30000	82.2	41.1	27.4	20.5	13.7	6.8	3.4
35000	95.9	47.9	32.0	24.0	16.0	8.0	4.0
40000	109.6	54.8	36.5	27.4	18.3	9.1	4.6
45000	123.3	61.6	41.1	30.8	20.5	10.3	5.1
50000	137.0	68.5	45.7	34.2	22.8	11.4	5.7

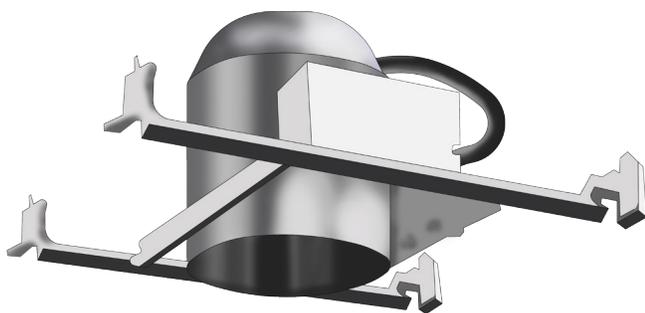
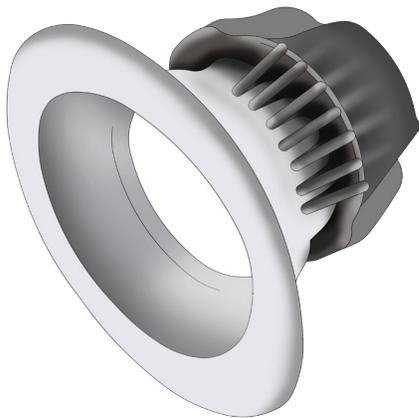
# Fixture Replacement Guide

## Troffers

Troffers can be either recessed or surface mounted, and traditionally are offered in sizes of 2'x4', 1'x4', or 2'x2'. Many LED fixtures exist in varying qualities and at a wide range of price points.

Benefits over fluorescent troffers include lower power consumption with matched lumen output, equal or better CRI, and precise CCT (often with internal color management technology). In addition, regular maintenance or lamp replacement is not necessary, and they are often dimmable.

For recessed LED troffers, select fixtures that are rated for the ceiling environment in which they are being installed. IC-rated fixtures are rated for direct contact with insulation in ceilings, while non-IC fixtures are not.



## Downlights

Traditional downlights are often offered as three components: a recessed housing, a lamp, and a trim (with or without a lens). When replacing a downlight with LEDs, the lamp can be replaced with an LED lamp, an integrated LED lamp and trim package, or the entire fixture can be replaced with an integrated LED package, which includes the housing, lamp, and trim. All three options offer the potential for energy savings. When replacing an existing lamp with an LED lamp, it is important to recognize that the recessed housing was likely designed for a specific technology such as incandescent lamps. Therefore, an LED lamp replacement has the potential to yield different light output, distribution, and heat properties (to name a few) than the intended lamp. In addition, a replacement lamp may not be the same size as the intended lamp and may not fit into the housing. It is recommended to test a desired LED lamp in a single fixture before fully investing to ensure a satisfactory outcome.

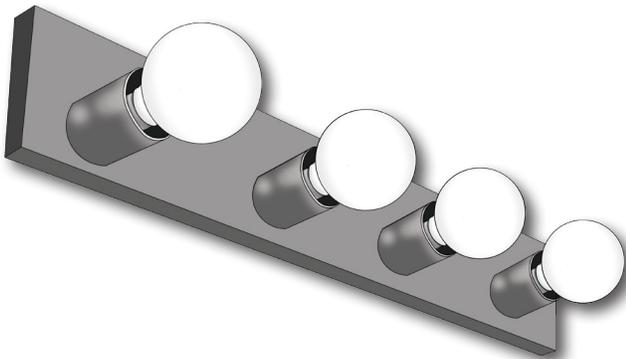
Some benefits of LED downlights include improved efficacy, no loss of life from rapid switching (CFLs will suffer loss of life from this), and matched lumen output.

When replacing downlights with LED products, pay attention to the operating temperature of the LED product so that the lifetime of the product is not compromised (see page 8 for more information).

## Ceiling Mount

Ceiling fixtures are often found in kitchens and bathrooms. They offer a central, often diffuse, light source that is easy to manage. Traditional ceiling fixtures have sockets for 1 to 3 lamps. When considering LEDs, an existing fixture can be either re-lamped using LEDs or completely replaced with a new LED fixture.

When re-lamping a ceiling-mounted fixture inside a residence, it is important to consider the number of hours per day that the fixture will be on, which is often difficult to gauge. If the fixture is going to be used for less than 3 hours per day, it is possible that the cost/benefit of replacing CFLs with LED lamps in an existing fixture may not result in a reasonable payback. For ceiling-mounted fixtures used for 4 or more hours a day, as in a kitchen, the payback may occur more rapidly. A full fixture replacement with a LED fixture that uses less overall power may be more justifiable.



## Stairwell Wall Mount

Wall-mount fixtures in stairwells are either linear fluorescent-type fixtures or round fixtures with one or two sockets. Local building code generally requires a minimum light level in stairwells 24 hours per day. Linear LED fixtures available at the time of this publication typically reduce energy use by approximately 10% - 20%, which in the case of stairwells can yield substantial overall energy savings. However, fixture prices are currently high, making a reasonable payback difficult. As fixture prices come down over time, the time to payback will also come down, making LED fixtures an attractive option. For fixtures with one or two screw-base sockets, using long-lasting LED lamps may offer some energy and money savings.

## Bathroom Vanity

Wall-mount fixtures found in bathrooms cast light on an occupant's face, making it easier for them to see themselves in a bathroom mirror. When re-lamping vanity fixtures inside a residence, it is important to consider the number of hours per day that the fixture will be on, which is often difficult to gauge. If the fixture is going to be used for less than 3 hours per day, it is possible that the cost/benefit of replacing CFLs with LED lamps in an existing fixture may not result in a reasonable payback. A full fixture replacement with a LED fixture that uses less overall power may be more justifiable.



## Wall Packs

Wall packs are used outdoors to light up walkways and parking lots, and to provide visibility and security for nighttime outdoor activities. Traditional wall packs use metal halide (MH) or high pressure sodium (HPS) lamps. These fixtures are often inefficient, wasting much of the light produced by the lamp.

LED wall packs are offered in a broad range of light outputs ranging from 500 lumens to over 11,000 lumens. A typical traditional wall pack will emit around 4,000 lumens using a 175 W MH lamp. An LED wall pack, on the other hand, can deliver the same 4,000 lumens using, on average, 56 watts. Some LED products will use as little as 40 W for the same output. LED wall packs will generally have better color maintenance, and lifetimes up to five times longer than traditional wall packs.

Retrofit kits are also available for existing wall packs; however, they come with a number of problems that are better avoided by simply upgrading to LED wall pack fixtures.



## Post-top Fixtures

Post-top fixtures are used in conjunction with wall packs, distributing light to areas of walkways and parking lots that wall packs are unable to illuminate. Traditional post-tops use MH or HPS lamps, which will have the same properties as wall packs.

Integrated LED post-top fixtures have the potential for high energy savings for the same output as traditional technologies, as well as offering a wider variety of CCTs from which to choose.

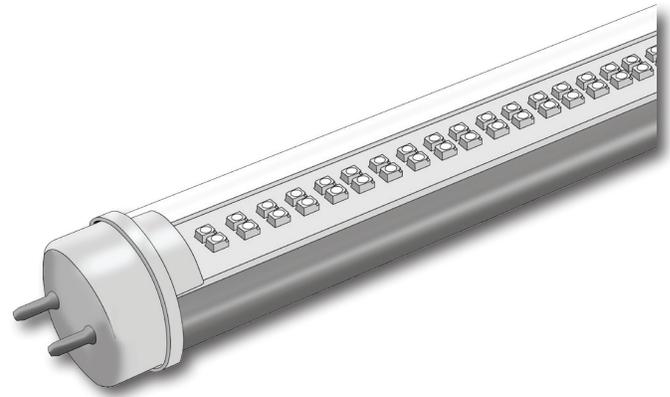
While retrofit kits are available for post-tops, they come with a number of problems that are better avoided by upgrading to integrated LED fixtures.

# Lamp Replacement Guide

## Linear Lamps

While traditional fluorescent lamps emit light in all directions, most typical LED linear replacement lamps only emit light in one direction. Due to the directionality of these lamps, a lower lumen output is often acceptable as a replacement for linear fluorescent lamps. There is a limit to how much lower the lumen output can be, however. In many cases, a 4-ft T8 linear fluorescent lamp, which emits approximately 2950 lumens, can be replaced with a 4-ft linear LED lamp that emits around 2200 lumens. This is because 30% or more of the light that is emitted by a linear fluorescent lamp is lost inside the fixture, while the losses from a linear LED lamp are typically lower than 10%.

Make sure the fixture into which an LED lamp is being placed can accommodate the extra weight – LED lamps are heavier than their fluorescent counterparts. Also inspect the warranty information included with the lamp. As of this printing, many linear LED lamps have a tendency to have individual LEDs fail before the warranty period is over. Also important is the color information included with the lamp. Make sure that the CCT is the same for all lamps used in a single space.



### *Caution*

When purchasing replacement lamps for linear fixtures, make sure you read the installation guide carefully. Many LED linear replacement lamps require a certified electrician to bypass the fluorescent ballast for proper use. Connecting a lamp to a fluorescent ballast for which it is not designed can result in catastrophic failure, electrical malfunction, or worse.



## A-lamps and Globes

Table and floor lamps are used in living rooms and bedrooms inside the home, as well as in recreational common areas. These fixtures often provide task light as well as ambient light for the room in which they are used. When switching the lamps in the fixture from an incandescent lamp to an LED lamp, pay attention to the distribution of LED replacement lamps, which may not be the same as an incandescent lamp or CFL. As seen in the image, the table lamp on the right uses a lamp that emits light in all directions. Both incandescent lamps and twist CFLs have this type of distribution. The table lamp on the left uses a lamp that does not emit light in all directions. Many LED replacement lamps have this type of distribution.

Globe lamps, which are often used in vanity fixtures, are similar to A-lamps when comparing technologies.

## BR- and PAR-Lamps

Recessed downlights traditionally use BR- or PAR-type lamps, and generally range in size from R20 to R38. These reflector lamps emit light in a specific direction and can be found labeled as “narrow” or “flood” to denote the size of their distribution. Replacing incandescent or halogen BR- or PAR-type lamps with LEDs can save energy without having to replace the housing in which they are being placed.

Make sure that the fixture into which an LED lamp is being placed can accommodate the size and weight of the lamp, as LED lamps are heavier than their incandescent or CFL counterparts.

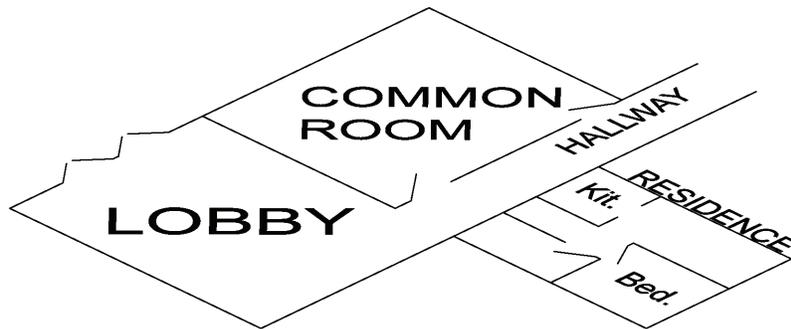


# Lighted Rooms and Areas



The following section has design notes that can assist in selecting the right fixture or lamp for the room being lit. While many different lamp or fixture types may be suitable for a particular room, some lamps or fixtures will perform better than others due to the particular needs of that room. Lobbies and hallways, for instance, may need to be on 24 hours per day to meet code requirements and

would benefit from large area light sources such as a 2'x4' ceiling fixture (either recessed troffer or surface mounted). The same troffer, however, would not be suitable for a small bathroom. Kitchens may need large area lighting but may not have the space to accommodate a 2'x4' fixture, so a ceiling mounted fixture, with either integrated LEDs or multiple LED lamps, may be more suitable.



## Common Areas

Common areas are often in use at all hours of the day, meaning that often, the lighting is on for long periods of time. Choosing LED fixtures will result in energy savings. The amount of light needed will vary depending on the space, so be sure to pay attention to the activities that take place in each common area. For some spaces, such as community rooms, good color rendering of objects and a warm-white color appearance help make the space visually attractive. For areas such as hallways and stairwells, it is important to meet minimum light levels

specified by building code.

For increased energy savings, controls such as occupancy sensors can be used in many areas that have lighting on for long periods of time with low traffic. Be aware that when utilizing dimming, although LEDs are inherently dimmable, compatibility issues exist between some dimmers and dimmable LED lamps and fixtures which can result in flicker, reduced light output, and buzzing. Check lamp product information for a list of compatible dimmers.



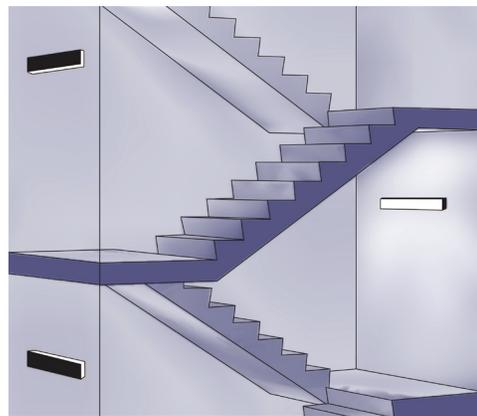
## Common Areas: Hallways

Hallways, often due to building code, need to have lighting on 24 hours per day. Large savings can be realized by reducing the total power consumption of the lamp and/or fixture. Efficacy is more important in hallways than CRI and CCT; however, CRI should still be greater than 80 and CCT should be less than 5000 K.

Troffers and downlights are often used to light hallways. For more information, see page 12 regarding troffers and downlights.

## Common Areas: Stairwells

Stairwell lighting is important as it must satisfy various codes in terms of minimum light levels and time on (often 24 hours per day), as well as be bright enough for residents to feel safe. As in hallways, efficacy is most important to achieve energy and cost savings; however, CRI should be greater than 80 and CCT should be less than 5000 K. Choosing surface-mount LED fixtures (page 13 for more information) will result in energy savings.

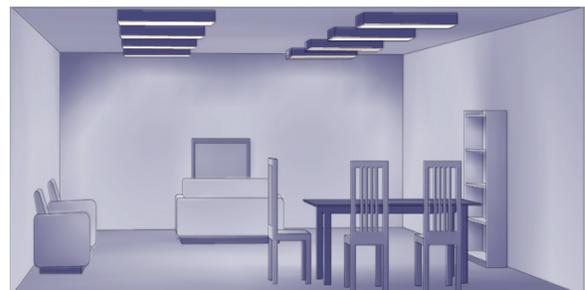


## Common Areas: Lobby

Lobbies in multi-family housing are often illuminated 24 hours per day. Some lobbies may have large windows with plenty of daylighting, in which case it may be possible to dim or turn lights off when the space has sufficient daylight using photosensor controls. High efficacy should be balanced with reasonable CRI (over 80), and CCT should be consistent across all lamps or fixtures. Review local codes to determine the minimum acceptable lighting level for a dimmed setting.

## Common Areas: Community Room

A community room is a space that can be used for many different kinds of activities: reading, TV watching, puzzles, parties, meetings, and more. For general lighting, troffers (page 12 for more information) are often used. Adding task lighting such as floor or table lamps (page 15 for more information) to a general lighting scheme can provide enough versatility to a common space to suit its many uses.



## In the Home

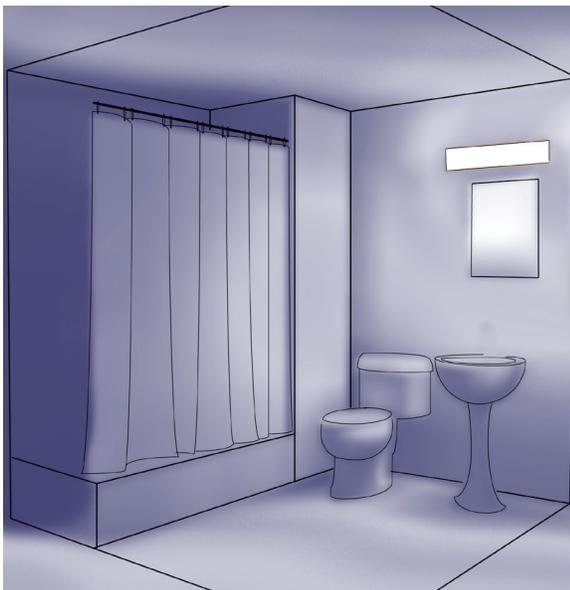
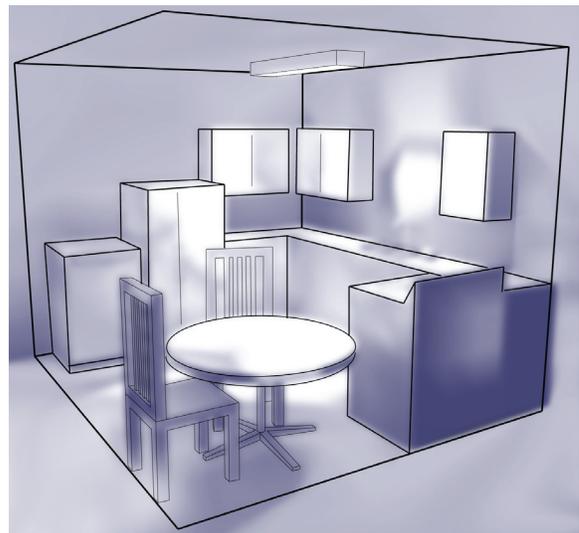
The lighting of a home's interior is important to the resident's comfort and ability to conduct daily tasks. Permanently installed lighting in a multi-family housing apartment usually consists of overhead lighting in the kitchen and bathroom, and perhaps in the apartment entrance.

CRI and CCT are important in living spaces. The CRI of light sources should be high in order to accom-

modate color-sensitive tasks that happen in the home, such as cooking or distinguishing between a pair of black or navy blue socks. Lighting with a high CRI (>80) is recommended. CCT preference in North America is often 2700K – 3500K; however, with so many choices available, be sure that multiple lamps in the same room all have the same CCT.

## In the Home: Kitchen

Choosing lamps and fixtures with high CRI is an important factor for a kitchen in order to perceive colors. Most food preparation occurs on the kitchen counter top, and lamps with a CRI above 80 will help occupants to differentiate subtle colors in food and labels. Kitchens will typically have ceiling-mounted fixtures (page 13 for more information) or surface-mounted troffers (page 12 for more information).



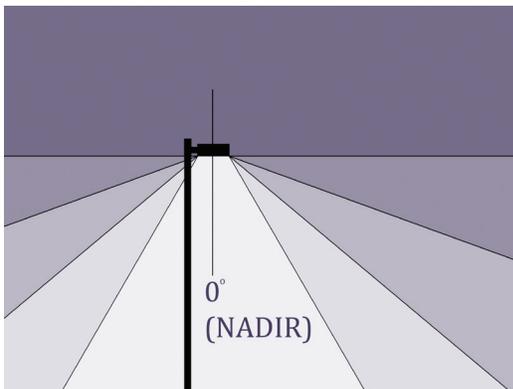
## In the Home: Bathroom

An important visual task in a bathroom is viewing oneself in the mirror. Directing light to the person, not to the mirror, will improve visibility for this task. Wall-mounted vanity fixtures (page 13) are often used in bathrooms and can be supplemented by ceiling-mounted fixtures (page 13) for larger bathrooms requiring more ambient lighting.

It is also important to maintain high ambient light levels in the bathroom and in the shower to help those with low vision to keep surfaces clean, and to maneuver safely in and out of the tub or shower.

## Exterior Lighting

Outdoor security lighting is meant to create an environment around the periphery of a property that feels safe and secure to residents using the entrances and exits at night. The main factors to consider when deciding on outdoor security fixtures are illuminance, uniformity, and distribution. Traditional outdoor lighting fixtures and lamps are able to produce a high amount of light. People may see better with more light; they can respond faster and have better acuity and color vision, which is important for identification. On the other hand, too much light can cause glare problems. It is important to try to match the lumen output of an existing installation when completing an LED lighting upgrade. Non-uniform lighting, caused by poor fixture placement or poor distribution, can create confusion and can limit people's ability to see or identify people or objects that are potentially dangerous. Non-uniform lighting can be even more disturbing for the elderly, who may have a harder time adapting from areas of high light to areas of low light, and may interpret shadows as edges. In most cases, higher light levels for an outdoor lighting installation is better. However, lights shining into the sky, into neighboring properties, or into resident's eyes can be problematic.



### ***Cut-off***

When buying exterior light fixtures, it is important to make sure the lighting is reaching only the places where it is needed and not throwing light onto neighboring properties, into residences, or upward to the sky. Spill light leads to many issues such as light pollution, glare, and wasted energy. If the fixture is emitting a significant amount of light more than 90° above nadir (shown in the figure), it can contribute to a type of light pollution called sky glow. When choosing fixtures for exterior spaces, choose partial cut-off or fully cut-off fixtures.

# Typical Metrics for Common Lamp Types

Lamp Type	Power (watts)	Efficacy (lumens per watt)	Light Output (lumens)	Life (hours)	
	Incandescent A-lamp	60	15	880	1,000
	Incandescent A-lamp	75	16	1,200	750
	Incandescent A-lamp	100	17	1,700	750
	Incandescent globe lamp	40	9	375	2,000
	Incandescent globe lamp	60	11	650	2,000
	BR30 incandescent reflector lamp	65	9	610	2,000
	BR40 incandescent reflector lamp	65	10	635	2,000
	BR30 halogen IR reflector lamp	45	17	745	3,600
	PAR30 halogen reflector lamp	50	12	610	2,800
	PAR30 halogen reflector lamp	75	13	1,000	3,000
	PAR38 halogen reflector lamp	90	15	1,320	3,500
	PAR38 halogen reflector lamp	120	15	1,800	3,000
	4-foot T12 linear fluorescent lamp	40	73	2,900	20,000
	3-foot T12 linear fluorescent lamp	30	78	2,350	18,000
	2-foot T12 linear fluorescent lamp	20	63	1,265	9,000
	4-foot T8 linear fluorescent lamp	32	89	2,860	25,000
	3-foot T8 linear fluorescent lamp	26	83	2,150	20,000
	21-inch T5 linear fluorescent lamp	13	71	920	7,500
	Screwbase CFL	14	59	825	10,000
	Screwbase CFL	23	70	1,600	10,000
	Covered CFL (A-lamp shape)	15	53	800	8,000
	Covered CFL (globe-shape)	9	56	500	8,000
	Covered CFL (globe-shape)	14	57	800	8,000
	Covered CFL (globe-shape, with candelabra-base)	9	50	450	8,000
	Covered CFL (capsule-shape)	14	57	800	8,000
	Covered CFL (capsule-shape)	19	58	1,100	10,000
	Covered CFL (reflector-shape)	15	48	720	8,000
	Covered CFL (reflector-shape)	23	53	1,200	8,000
	CFL (GU24 Base)	9	56	500	10,000
	CFL (GU24 Base)	13	69	900	10,000
	CFL (GU24 Base)	18	67	1,200	10,000
	CFL (GU24 Base)	26	69	1,800	10,000
	Screwbase LED (A-lamp shape)	12	67	800	25,000
	Screwbase LED (A-lamp shape)	14	79	1,100	25,000
	Screwbase LED (globe-shape)	8	55	440	50,000
	Screwbase LED reflector (PAR20 shape)	9	56	500	40,000
	Screwbase LED reflector (BR30 shape)	13	56	730	25,000
	Screwbase LED reflector (PAR30 shape, outdoor-rated)	15	60	900	30,000
	Screwbase LED reflector (PAR38 shape, outdoor-rated)	24	54	1,300	25,000

# Glossary

**A-lamp** A screw-base lamp with a bulbous envelope that surrounds the light source. The number after the 'A' designation (e.g., A19) refers to the diameter of the bulb at the widest point, in eighths-inches (an A19 is 2-3/8 inches at its widest point).

**ambient lighting** Lighting that is designed to provide a substantially uniform light level throughout an area, exclusive of any provision for special local requirements.

**ballast** A device that is used with a fluorescent or high-intensity discharge lamp to provide the necessary circuit conditions (voltage, current, and wave form) for starting and operating the lamp.

**BR-lamp** A reflector lamp with a bulged neck that is wider in diameter than the screw base.

**color rendering index (CRI)** A metric for describing the effect of a light source on the color appearance of objects being illuminated, with a CRI of 100 representing the reference condition (and thus the maximum CRI possible). In general, a lower CRI indicates that some colors may appear unnatural when illuminated by the lamp. The CRIs of two or more lamps should only be compared if the lamps have the same correlated color temperature.

**control** A mechanism to turn lamps on and off, or to dim lamps. Controls include switches, dimmers, timing devices, motion detectors, photosensors, and central control systems.

**correlated color temperature (CCT)** Describes the color appearance of the light that is produced, in terms of its warmth or coolness. The CCT relates the color appearance of the lamp to the color appearance of a reference source when the reference source is heated to a particular temperature, measured on the kelvin (K) temperature scale. A low color temperature (3500 K and lower) describes a warm source, such as a typical incandescent lamp and a warm fluorescent lamp. A high color temperature (4500 K and higher) describes a cool source, such as a cool white fluorescent lamp.

**dimmer** A device used to lower the light level, or amount of light emitted by a fixture, by controlling the voltage or current available to it.

**directional distribution** Radiating in a specific direction.

Directional light sources provide illumination on work surfaces or on objects, or in a particular direction. This type of light distribution is typically used to provide a higher light level than that of the surrounding area. See also *omni-directional distribution*.

**efficacy** The total light output of a light source divided by the total power input. Efficacy is expressed in lumens per watt (lm/W).

**energy** The product of power (watts) and time (hours), expressed in watt-hours (WH). Energy used for lighting can be saved either by reducing the amount of power required or by reducing the amount of time lighting is used.

**fixture** A complete lighting unit consisting of a lamp or lamps, together with the parts designed to distribute the light, to position and protect the lamps, and to connect the lamps to the power supply. Also referred to as a light fixture, luminaire, fitting, or unit.

**fluorescent lamp** A lamp containing mercury under low pressure, relative to high-intensity discharge lamps. The mercury is ionized by an electric arc, producing ultraviolet energy which, in turn, excites phosphors coating the inside of the lamp to fluoresce.

**footcandle** Imperial unit of illuminance equal to one lumen per square foot. One footcandle equals 10.76 lux.

**glare** The loss of visibility and/or the sensation of discomfort associated with bright light within the field of view.

**IC-rated** Fixtures that are IC rated are rated by Underwriters Laboratories (UL) for direct contact with insulation up to a maximum power value (such as 75 W). Fixtures that are non-IC rated require a space of at least 3 inches between housing and insulation.

**illuminance** The density of luminous flux incident on a surface. Illuminance is the luminous flux divided by the area of the surface when the surface is uniformly illuminated. Illuminance is calculated as the amount of lumens per unit area.

**incentive** A reimbursement of a portion of the cost of a product. Incentives commonly are offered by electric utilities and manufacturers on some energy-saving lighting products. Also known as *rebates*.

**initial cost** The original cost of equipment, lamps, and installation, exclusive of operating costs such as energy, maintenance, and lamp replacement.

**kelvin (K)** The standard unit of temperature that is used in the Systeme Internationale d'Unites (SI) system of measurements. The kelvin temperature scale is used to describe the correlated color temperature of a light source.

**lamp** A manufactured light source including the bulb, the base, and the internal structure that produces light, either a filament or an arc tube. Lamps are often referred to as light bulbs. The term lamp also is commonly used to refer to plug-in luminaires, such as desk, floor, and table lamps.

**light distribution** The pattern of light that is produced by a lamp or a fixture, or the patterns of light created in a room. See also *directional distribution* and *omni-directional distribution*.

**light-emitting diode (LED)** A semiconductor chip that emits light when an electrical current flows through it. The color of the LED light depends on the chip's substrate materials and packaging. LEDs in the past have been used as indicator lights and in emergency exit signs and traffic signals. Today, white LED lighting is available for many types of general lighting applications.

**light output** Luminous flux, measured in lumens. The light output rating of a lamp is a measure of its total integrated light output. See also *lumen*.

**linear fluorescent lamp (LFL)** Any of the family of straight tubular fluorescent lamps. Lamps are available in 6-inch to 8-foot lengths, with the most-common length being 4 feet.

**lumen** The unit of luminous flux. The lumen is the time rate of flow of light.

**lumens per watt (lm/W)** See *efficacy*.

**lux** Standard international unit of illuminance equal to 1 lumen per square meter. One lux equals 0.0929 foot-candles.

**metal halide (MH) lamp** HID light source in which radiation from a mixture of metallic vapor and additives of halides (e.g., sodium, thallium, indium) produces visible light.

**mounting height** The distance from the floor to the lamp center of the fixture or to the plane of the ceiling for recessed equipment. Motion detectors also have a recommended mounting height.

**nadir** The direction pointing directly below a particular location. The nadir at a point on the earth is the local vertical direction pointing in the direction of the force of gravity at that location.

**omni-directional distribution** Radiating equally in all directions. See also *directional distribution*.

**PAR-lamp** PAR stands for parabolic aluminized reflector. A PAR-lamp uses an aluminized reflector to create a beam of light in the shape of a parabola (oval).

**recessed fixture** A fixture that is mounted above the ceiling (or behind a wall or other surface) with the opening of the fixture flush with the surface.

**simple payback** A term to define the time required to save enough in operating costs by using any retrofit design, compared with the existing design, to pay back the incremental cost of the retrofit.

**socket** The fitting on a fixture that electrically connects the fixture to the lamp.

**surface-mounted fixture** A fixture mounted directly on a ceiling or other surface.

**switch** A device that turns a lamp or lamps on or off by completing or interrupting the power supplied to the lamp(s).

**task lighting** Lighting that is directed to a specific surface or area. Task lighting provides illumination for visual tasks.

**troffer** An inverted trough (or ceiling coffer) that serves as the support, connection, and sometimes reflector for a fluorescent or LED lighting unit.

**vanity light** A wall-mounted fixture located next to a mirror.

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