The Maxlite BR30 (left) and BR40 replace incandescent lamps (65W and 90W, respectively) in standard Edison-type sockets. Both lamps are available in 2,700K and CRI80-plus (maxlite.com).

# LED Lighting Essentials

Unlike incandescent bulbs, LEDs are high-tech electronic devices. Here's what you need to know to make the right choice

by Fernando Pagés Ruiz

How many contractors does it take to screw in an LED bulb? Well, just one, but only after a bit of head scratching. While new technology has made every aspect of our lives richer and more efficient, it has complicated simple things like choosing and changing a light bulb. Shopping for LED bulbs is like shopping for a smart phone — it can make you feel stupid, because there are so many choices and a lot of what you thought you knew about light bulbs doesn't apply to LEDs. In what follows, we'll look at the key concepts you need to learn to help your clients make the right decision.

## Buying LED Lamps

Incandescent bulbs are fairly consistent. Despite differences in bulb shape and base, almost all incandescent bulbs of a particular wattage deliver the same quantity of light. And although manufacturers have introduced frosted and colored glass to create special effects, the quality of incandescent light is fairly reliable as well. With incandescents, you can mix brands, and it doesn't matter where or when you buy the bulbs.

LEDs are not so simple. Some characteristics are the same, bulb to bulb and brand to brand, but some are not. When asked what a contractor should focus on when venturing into LEDs, Jeff Dross, corporate director of education and industry trends for Kichler lighting, offered this caution: "Keep in mind that you're moving from the real simple architecture of the Edison bulb to a piece of electronics."

For now, while the public gets used to

### Lumen-Watt Equivalence

| Light Output (lumens) | Watts | | |
|---|---|---|---|
| | LED | CFL | Incandescent |
| 450 | 4–5 | 8–12 | 40 |
| 300–900 | 6–8 | 13–18 | 60 |
| 1,100–1,300 | 9–13 | 18–22 | 75–100 |
| 1,600–1,800 | 16–20 | 23–30 | 100 |
| 2,600–2,800 | 25–28 | 30–55 | 150 |

When buying an incandescent bulb, we look for wattage — which refers to energy consumption — and pay no attention to lumens, the measure of how much light the bulb produces. With LEDs, however, which use very little energy, lumens are the common unit of measure. To use this chart, match the wattage of the incandescent you want to replace to the LED that corresponds to the lumens the incandescent produces.

### Cost Comparison: LEDs vs. CFL vs. Incandescent

| | LED | CFL | Incandescent |
|---|---|---|---|
| Light bulb projected lifespan[1] | 50,000 hrs | 10,000 hrs | 1,200 hrs |
| Watts per bulb (equiv. 60 watts) | 10 | 14 | 60 |
| Cost per bulb[2] | $35.95 | $3.95 | $1.25 |
| Kwh used over 50,000 hrs | 300–500 | 700 | 3,000 |
| Cost of electricity (@ 10¢ per kwh)[3] | $50 | $70 | $300 |
| Bulbs needed for 50k hours of use[4] | 1 | 5 | 42 |
| Equivalent 50k hours bulb expense[5] | $35.95 | $19.75 | $52.50 |
| Total cost for 50k hours | $85.95 | $89.75 | $352.50 |

**Energy Savings** over 50,000 hours, assuming 25 bulbs per household:

| | LED | CFL | Incandescent |
|---|---|---|---|
| Total cost for 25 bulbs | $2,143.75 | $2,243.75 | $8,812.50 |
| Savings to household by switching from incandescent | $6,668.75 | $6,568.75 | 0 |

[1]Lifespan is projected because of the time required to test.
[2]Cost per bulb is based on an average for a 60-watt equivalent LED bulb.
[3] Cost of electricity varies by location.
[4]Bulb breakage not considered. Incandescent bulbs and CFL bulbs break more easily than LEDs, increasing their cost of use.
[5]Most LEDs come with a minimum 2-year guarantee. Any defective LED bulb will usually fail within this time.

Although LEDs and CFLs are less expensive than incandescents in the long run, high initial cost makes replacing all of a home's lamps impractical for most homeowners. Because of their long life, LEDs are a good choice for any fixture that operates for three or more hours daily, or for hard-to-reach fixtures where changing the bulb is difficult. ***This table was adapted from Eartheasy (eartheasy.com).***

them, LEDs are mostly defined in terms of their "equivalence" to incandescent bulbs — even though they perform very differently (see "Lumen-Watt Equivalence," top left). For example, while everyone knows what to expect from a 40-watt or 100-watt incandescent bulb, very few people know that the amount of light these lamps produce ranges from about 400 lumens to about 1,600 lumens. We are accustomed to thinking of the brightness of a bulb in terms of the wattage it draws. But the power consumption of LEDs is so low it is almost irrelevant, which makes it all the more important to understand light output in terms of lumens.

***Base and shape.*** LEDs come in a variety of sizes and shapes, but the most affordable at the moment cost between $10 and $15 per bulb (see "Cost Comparison," left center), mimic the traditional A19 or PAR shape, and fit the ever-present Edison screw base (see photo, previous page). That said, you will also find many LED brands offering the MR16 shape with a bi-pin base, as well as LEDs made to fit a range of bi-pin sockets between GU4 and GU10. You can also find LEDs in fluorescent-style tubes of several diameters and lengths, as well as in floodlights, recessed can lights, puck lights, undercabinet lighting, and more.

***Dimmers.*** Many LED lamps work with conventional dimmers, although not as effectively as incandescent bulbs. Because LEDs require so little energy to function (typically 3 to 5 volts), they need a transformer to ratchet down the current. This is one reason LEDs don't dim like incandescent lights, which run at standard line voltage. Dimming an incandescent light not only reduces lumens, it changes the color temperature, which goes from 3,000K or 2,700K to a yellow/orange 1,400K–1,200K. ("Color temperature" is counterintuitive in the sense that higher color temperatures produce "cooler" white light and lower temperatures produce "warmer" yellow light; see "Color Temperature Scale," page 52). But when

an LED dims, it does not change color; only the amount of light changes. Because U.S. consumers have grown accustomed to the color shift that happens with incandescents, LED manufacturers have developed color-shift technology to replicate it. This technology is available in either the lamps or the LED-compatible dimmers, both of which are currently expensive options.

***Mixing brands.*** You don't want to mix and match two LED brands in a single circuit any more than you would mix and match two brands of "weathered wood" roof shingles. Two lamps with the same lumens (or watt equivalency) may have different color temperature, color quality, and light dispersion characteristics. This can create unusual effects and change the way colors are perceived. Most of the relevant information is printed on the lamp, the lamp packaging, or the manufacturer's spec sheet (see "Lighting Facts Label," page 56).

## Selective Replacement

Jeff Dross recommends treading slowly into the future of lighting. If a homeowner has good CFLs and doesn't mind the light quality, there's no need to replace every fixture in a house with LEDs, he says. But for certain applications, LEDs work very well. "Think about where you're using the most light most of the time," Dross says. "This is where they would make sense economically ... Choose lights that burn a minimum of three to six hours a day."

Another good candidate for conversion to LED are light fixtures in remote locations, such as recessed cans along the ridge of a 20-foot-high cathedral ceiling (or anywhere an extension ladder would be required to change the bulbs).

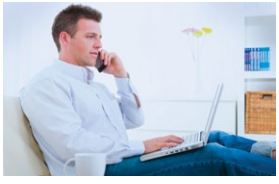
***New applications.*** The small size and extremely low voltage requirements of LEDs have designers thinking about putting these lamps in places where lights have never been. LED tape, for example, is now less expensive and more reliable than the incumbent technology, and is an excellent choice for accent lighting or to outline stairs, doorways, or toe-kicks (see photo on page 54, bottom left).

Once you are no longer bound by traditional lighting concepts, you will find that

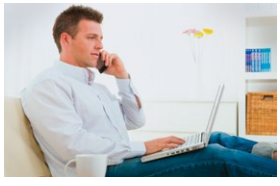
## Color Temperature Scale

Because we typically associate "temperature" with heat production, color temperature (CT) can be confusing. On the CT scale, which expresses electromagnetic radiation in degrees Kelvin (K), higher values apply to "cool" bluish white light, while lower values apply to the "warm" yellowish light of incandescents.

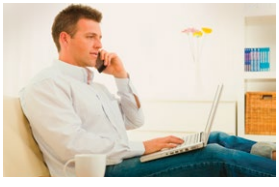
A related measure called the color rendering index (CRI) assesses how faithfully a lamp reproduces colors compared with natural light. Look for a CRI of at least 75, which is the Energy Star minimum. But many LEDs are available in CRI 85 or higher, which will generally provide very good-quality lighting.



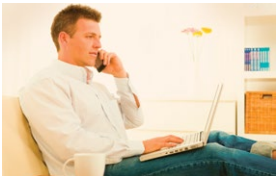
6,400K Overcast Daylight



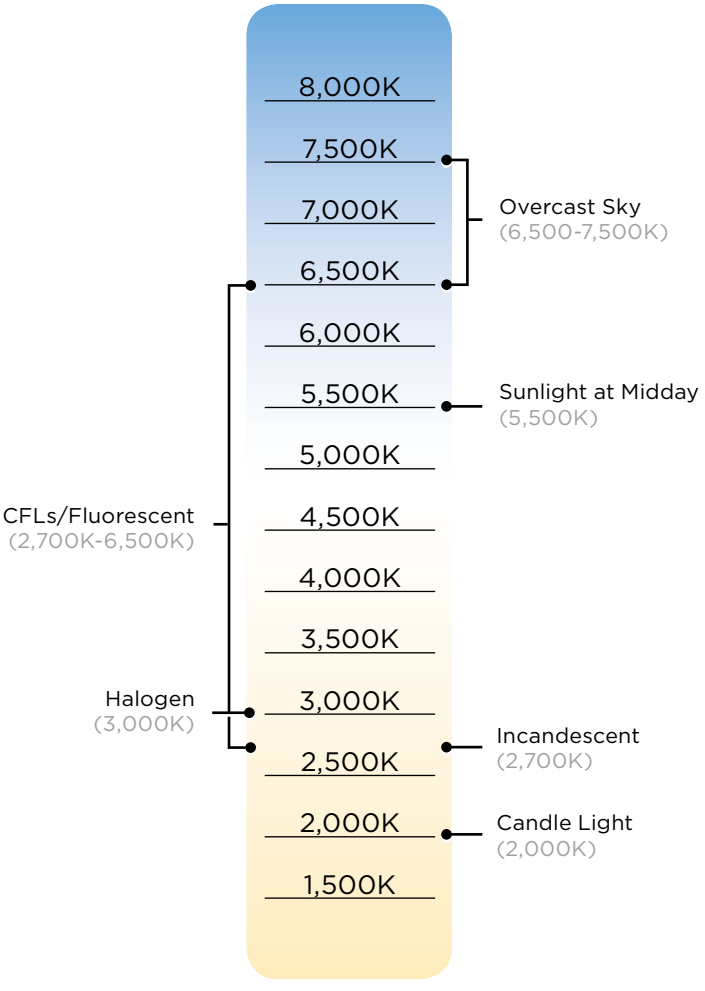
5,500K Daylight



4,100 Cool White



2,700K Warm White



TivoTape from Tivoli (tivolilighting.com) is a low-voltage indoor-outdoor light strip with an adhesive backing. It's sold in lengths up to 16 feet and can be cut in the field. The LEDs are fully dimmable and come in a variety of light temperatures, including four whites and red, yellow, blue, and green.

there is a growing assortment of lighting applications for LEDs that would be impractical or impossible with incandescent lamps. These include lighting that responds immediately to changes in the environment — that dims, for example, when someone turns on the TV; medical lighting, such as light-emitting blankets for babies with jaundice; and fixtures for high-humidity environments, such as spa lighting and landscape applications.

Unlike tungsten filament lighting, LEDs come with solid-state circuitry that can take a stiff bump, even when warm, so they are a good choice for vibration- and impact-resistant lighting. LEDs can also withstand cold to about -40°F, but they do not work well in hot environments. In fact, many lamps require a minimum amount of air circulation and come with a warning to avoid enclosed fixtures. That means you won't find LED oven lighting anytime soon.

***Stars Wars lighting.*** Thus far LEDs have been subject to Haitz's Law, which forecasts a tenfold drop in price every decade coupled with a 20-fold increase in performance. Recently, for instance, Philips announced a breakthrough bulb that produces a record 200 lumens per watt (lm/W) of warm, high-quality light. By comparison, the highest efficiency bulbs commercially available today deliver about half that efficiency (100 lm/W), and a regular incandescent bulb scarcely delivers 15 lm/W. Philips says the 200 lm/W LED will hit the market in 2015.

Some of the characteristics that make shopping more complicated for an LED than for an ordinary incandescent also provide clues as to what we can expect from this technology in years to come. For example, the variation in color temperature and light quality that makes it necessary to buy bulbs in batches has the benefit of allowing a single bulb to provide a range of lighting options far beyond what a conventional dimmer could supply. With simple computer controls, a single LED lamp like the IP-addressable


The Hue from Philips (meethue.com) is a home lighting system that includes proprietary LED lamps capable of displaying 16 million color variations. The lamps are controlled through a base unit that connects to an existing wireless network and can be operated via any iOS or Android device, or through a Web-based application. The system enables users to schedule lighting tied to behavior patterns, and includes a feature called "geofencing," which can adjust lighting based on detection of a mobile device carried by a homeowner approaching or leaving the home.

Philips Hue (see photo, above) can provide a range of color temperatures from candlelight to daylight in all the colors of the rainbow. And someday soon, lamps will tune to each other — so we won't have to worry about mixing bulbs — and will respond to environmental changes or lighting profile programs, in much the same way that smart thermostats do today.

On the cutting edge are organic and polymer LEDs (OLEDs and PLEDs, respectively), which consist of sheets of carbon or polymer-based compounds that glow when a current is applied. While not yet commercially available on a practical scale, OLEDs and PLEDs will make the surface-mount ceiling fixture a thing of the past. Instead, you'll apply a thin film to a wall or ceiling that will glow in whatever color you like, providing highly efficient, inexpensive light.

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# Lighting Facts Label

Since January 1, 2012, the FTC has required manufacturers to display a "Lighting Facts Label" on the packaging for medium screw-base LEDs (see example at right). It contains information about brightness, cost, life expectancy, energy used, and color temperature, and is intended to help consumers compare lighting products.

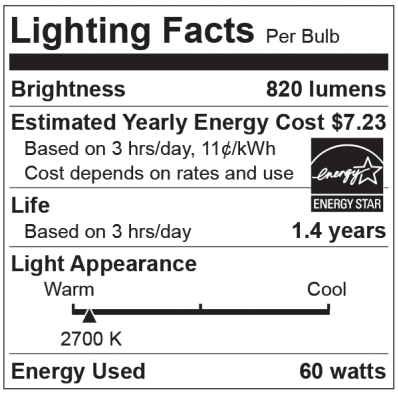
A similar label developed by the DOE applies to all solid-state lighting, not just screw-base LEDs (see example below). Unlike the FTC label, which is mandatory but does not require data verification testing, participation in the DOE labeling program is voluntary, but manufacturers must provide test results to verify performance claims. The DOE label includes most of the information on the FTC label plus the lamp's color accuracy, overall efficiency, and test compliance.

To avoid confusion, the DOE does not encourage use of its label on any product packaging bearing the FTC label, but the DOE label does appear on participating manufacturer specification sheets. Performance data for specific lighting products can also be found at lightingfacts.com/products.

Labels with the EnergyStar logo also meet the following requirements:

- Brightness equal to or greater than incandescent or fluorescent lighting, and light well-distributed over the area lighted by the fixture;
- Output that remains constant over time, decreasing only toward the end of the rated lifetime. The minimum lifetime is 25,000 hours, often expressed as 22 years of use for three hours per day;
- Color quality that ensures that the light appears clear and consistent over time;
- Efficiency as good as or better than that of fluorescent lighting.

## FTC Label




## DOE Label