

LEDs for general illumination: energy codes, lumens per watt, and other lighting criteria

The lighting community needs to be able to evaluate LED lighting products in the same way as any other competing technologies. **Jeffrey Schwartz** of ICF Consulting Inc describes some of the relevant criteria.

As researchers continue to improve the efficacy of white LEDs, lamp and fixture manufacturers will ask the design community to specify LED sources for general illumination on interior-lighting projects. Efficacy, based on lumens per watt (lm/W), is a valuable tool for determining what lighting source a designer will specify in a particular application, but it is only part of the story.

Jim Brodrick, Manager of the US Department of Energy's (DOE) Lighting Research and Development program, is responding to the Solid State Lighting (SSL) industry's request for assistance in helping speed the commercialization of new SSL products for general illumination. He says "We have planned a number of commercialization-assistance activities to make certain that the DOE's substantial investment in new SSL technology results in widespread use of these technologies and in large benefits to the US economy." Those activities include ENERGY STAR specifications (see box), technology demonstrations, assistance for development of voluntary codes and standards, development and distribution of technical information and tools, technology procurements, design competitions, and support of training programs.

If LEDs are to become part of mainstream lighting design, then lighting practitioners must be able to evaluate LED light sources and luminaires (fixtures) for energy-code compliance and performance in the same way they evaluate other lighting products. Below are some of the considerations that go into selecting light sources and luminaires, and the information needed by lighting practitioners before the decision to use LEDs can be made.

Energy codes

The US Energy Policy Act of 1992 (EPAAct) is an important piece of legislation that set certain performance standards for lighting equipment. The EPAAct was later amended, requiring state building energy codes to meet or exceed ASHRAE/IESNA 90.1-1999 [1] by July 2004.

In addition to certain lighting-control requirements, 90.1 set the lighting power allowance (LPA) for different building types and space types. The LPA is based on watts per square foot (W/ft²). A typical example of LPA using the building method is 1.3 W/ft² for an office building. This means that in a 20,000 ft² office building the total lighting power allowance is 26 kW (20,000 × 1.3). →

ENERGY STAR for residential lighting

by **Tim Whitaker**

The ENERGY STAR program is a qualification route for products that meet strict energy-efficiency criteria set by the US Environmental Protection Agency (EPA) and the Department of Energy. All traffic signals that have been awarded the ENERGY STAR use LEDs, while many LED exit signs meet the eligibility criteria in the category of operating on less than 5 W per sign.

For residential light fixtures, the ENERGY STAR program aims to move consumers from traditional incandescent fixtures to those using high-quality fluorescent or other energy-efficient technologies. Version 4.0 of the eligibility criteria, which will become effective in October 2005, says that the minimum system efficacy is 50 lm/W for

lamps with a total listed power of 30 W, and there are higher efficacy limits for higher-power lamps. The lamp must have an average rated lumen maintenance of at least 80% of initial lamp lumens at 40% (at least 4000 h) of the rated lamp life. The color-rendering index must be at least 80 for compact fluorescent lamps, and must have a CCT with one of the following values: 2700, 300, 3500, 4100, 5000 and 6500 K.

The ENERGY STAR specifications do not currently include any provisions for LED fixtures. However, version 4.0 does include a temporary allowance for decorative LEDs. The document states that "LEDs used as decorative lighting elements in residential-lighting fixtures and ceiling-fan light kits are allowed, as long as the total wattage of the

LEDs does not exceed 5 W, the average LED system (LED driver) efficacy is at least 20 lm/W, and the LED is used to supplement a primary light source that meets all of the applicable performance characteristics outlined in the eligibility criteria."

The EPA also says that it "plans to develop more comprehensive specifications for LED performance as the technology advances and becomes more widely used for residential applications."

- **Energy Star program**

www.energystar.gov

- **Energy Star eligibility criteria for residential light fixtures**

www.energystar.gov/ia/partners/prod_development/visions/downloads/fixtures/RLF_V4FINALSpec.pdf

It is important for the LED community to understand that the installed interior-lighting power includes all power required by the luminaires to operate, including the demand from lamps, ballasts, current regulators and control devices. In the case of LED luminaires, this includes all the power used by the LEDs plus the drivers and any other electronic elements. Therefore, as we move from speaking about lm/W for individual devices to discussing general illumination luminaires, the total input wattage, including the driver wattage, must be readily available for evaluation by the lighting practitioner.

State and local codes can also establish other lighting requirements. For example, in California's Title 24 residential energy code, the definition of "high efficacy" luminaires is based on lm/W.

The current code only requires a minimum of 40 lm/W. However, from October 2005 new standards will take effect, and light sources will be considered high efficacy only if they comply with the figures in the table.

In the requirement for fixtures using pin-based fluorescent systems, only the watts of the lamp (not the ballast) need be considered.

LED luminaires can only be considered high efficacy if the "LED can be tested (according to UL) to be at least 40 lm/W on the line voltage input side of any power supply or other device." Otherwise the fixture is not considered high efficacy.

Light levels

Building energy codes were not created in a vacuum. They are based on the amount of light needed for various applications and tasks, and represent an appropriate energy consumption to meet that light level. For example, based on ASHRAE 90.1, a manufacturing situation is allowed 2.2 W/ft², while a warehouse is only allowed 1.2 W/ft². The difference is based on the fact that a manufacturing application will typically need a higher light level (typically 50 foot candles) than a warehouse (typically 10 foot candles) for workers to perform the normal tasks. Therefore, the manufacturing building may require more wattage to provide that higher light level.

Light levels are not determined only by the lamp lumens emitted inside the luminaire. Lighting practitioners must calculate how much of the light exits the luminaire and where that light is being delivered. The real question is, "How much light is being delivered to the work plane where the task is being performed?"

To perform these calculations lighting practitioners rely on luminaire photometric reports that are available in standard IES format for software applications and in hardcopy format to easily show the various

Title 24 Residential Lighting Standards

Lamp power rating	Definition of high-efficacy lighting (lm/W)
15 W or less	minimum 40
15–40 W	minimum 50
over 40 W	minimum 60

Source: California Energy Commission

lighting metrics. While these numbers may not make sense to the untrained eye, when input into a software program a complete photometric report can be developed that tells the lighting practitioner how much of the light is leaving the luminaire, and where it is going.

These numbers can be entered into lighting-design tools to create simulated lighting layouts that show the resulting light levels. The IES reports also calculate the luminaire spacing criteria that tell the practitioner the maximum distance luminaires can be spaced from each other at a certain height, and still provide uniform lighting.

LEDs have well-defined optics, and the LED community should work carefully with luminaire manufacturers to optimize every lumen, so that LEDs can compete more successfully with other sources. IES photometric files are necessary to allow lighting practitioners to validate the results.

Other lighting criteria

In addition to evaluating energy efficiency, the *IESNA Handbook* and section 6.8 of the *Facility Standards for Public Buildings*, published by the US General Services Administration, recommend that quality issues be considered on all lighting projects. Most clients expect good quality along with energy efficiency and low maintenance. Typical quality specifications include a measure of lumen maintenance, a specific CCT, good CRI and glare control.

- **Lumen maintenance** describes the rate of decline in light output over time of a light source. Manufacturers publish curves that can be used to predict lumen maintenance; usually this is expressed as a percent of initial light output at a given number of hours. The behavior of most conventional light sources is well understood, but the LED industry has yet to agree on a standard for measuring and publishing lumen maintenance. Another important factor is a light source's fluctuation

LED luminaires exceed requirements

In May, Permlight Products introduced a series of products for the new-home market, which it claimed exceed the lm/W requirements of Title 24 and ENERGY STAR version 4.0. The luminaires are available in standard efficacy (25–35 lm/W) and high efficacy (40–55 lm/W) versions, which contain different LED modules. The Enbryten products feature completely replaceable and serviceable LED technology, with the LED boards and the power supplies easily changed using just a screwdriver.

- **LED luminaires "will be installed in new homes by fall 2005"**

www.ledsmagazine.com/articles/news/2/5/15

At the end of June, Cyberlux Corporation announced that its Aeon Pro E task and accent home-lighting products had been measured at 55 lm/W by Independent Testing Laboratories Inc in Boulder, CO. The lab confirmed that Aeon products exceed the new Title 24 requirement for kitchen and bathroom lighting of 40 lm/W, which will

come into force in October 2005.

"The capability of solid-state lighting technology has advanced significantly," said Mark Schmidt, chief operating officer and president of Cyberlux. "Our Aeon Pro products harness this capability and give home builders, residential designers and home buyers a new, energy-efficient alternative to traditional lighting technologies."

- **Test lab rates Cyberlux LED lighting products at 55 lm/W**

www.ledsmagazine.com/articles/news/2/6/33

in light output as temperature varies. For example, fluorescent lamps dim as they get colder whereas LEDs get brighter, but at different rates for different technologies. Designers need to have quantitative information about any expected variation in light output. [3]

- **Correlated Color Temperature (CCT)** indicates the color appearance of the light emitted by a source, relating its color to that of light from a reference source when heated to a particular temperature, measured in degrees Kelvin (K). Numbers below 3200 K represent a warm source similar to incandescent lamps, while those with a CCT above 4000 K are usually considered “cool”, or more like daylight, in appearance. Common CCTs used in general illumination are 2700, 3000, 3500, 4100, and 5000 K. The consistency of the color temperature over the life of the source is also important for uniformity of appearance. Practitioners need to know the color temperature and consistency of LED sources in order to blend them with other sources used in the same space.

- **Color rendering** is the ability of a light source to render the color of an object “correctly.” The CRI measures the source’s ability compared with a standard source of the same color temperature on a scale of 0–100. The higher the CRI the “truer” colors will appear. High CRI is important in applications where merchandise and people need to appear natural. High color rendering can also help to increase visual clarity and create a more pleasing and productive work environment. Lighting practitioners need to know the CRI of the LED sources being used in the luminaires. If, as some suggest, the color-rendering index (CRI) is not a good measure of LED lighting’s appeal to viewers, then the industry should develop an alternative metric.

- **Glare control** is another important issue in many applications. As LEDs improve in efficacy and in total lumen output per package, designers will be challenged to direct the light out, without causing annoying or discomforting loss in visual performance and visibility. Standard photometric reports provide lighting practitioners with some information to evaluate the level of glare.

Conclusions

As the LED research and manufacturing community continues to improve the efficacy of LEDs, manufacturers should go beyond talk of lm/W, and instead quantitatively describe system performance. Total system efficiency is important for meeting building energy codes but there is more to the story, which lighting designers want to hear.

The lighting community needs to be able to evaluate LED lighting products in terms of how much light comes out of the fixture and where it goes. They expect to be able to do that in the same way they evaluate other lighting products. They also need to be able to evaluate other characteristics such as color temperature, CRI and glare by the same standards used for other products.

When LED luminaires for general illumination are available, and this important information is properly provided, then lighting prac-

tioners can consider selecting LED products for specific applications. The final test will be the ability to justify those products based on their energy savings, lumen maintenance, life-cycle costs, and other design and quality benefits. ●

About the author

Jeffrey Schwartz, LC, IESNA, is a lighting technical specialist at ICF Consulting Inc. He is lighting certified and is items chairperson for the National Council on Qualifications for the Lighting Professions (NCQLP) Test Committee. He is technical specialist for the New York State Energy Research and Development Authority’s (NYSED) New York Energy Smart™ Small Commercial Lighting Program, and serves as a lighting consultant to several utilities and government agencies. Special thanks to Kathryn Conway of LED Consulting for her help in preparing this article.

Footnotes

[1] ASHRAE/IESNA 90.1. The American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc (ASHRAE) and the Illuminating Engineering Society of North America (IESNA) cosponsored the ASHRAE/IES 90.1 standard for energy-efficient design of new buildings, except low-rise residential buildings.

[2] Light-level recommendations are based on the *IESNA Handbook*.

[3] Source: Kathryn Conway, LED Consulting.

Links

DOE Building Energy Codes program: www.energycodes.gov

The Illuminating Engineering Society: www.iesna.org

US GSA Facility Standards for Public Buildings: www.gsa.gov

California Energy Commission, Title 24 program:

www.energy.ca.gov/title24