

Cree, Inc.

Energy-Efficient Lighting Lifecycle – White Paper

LED Lighting: More energy-efficient than CFL?

Monica Hansen
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Executive Summary

Energy-efficient lighting is a hot topic in today's discussions on climate change, sustainable energy policy and energy efficiency. Lighting consumes 22 percent of the electricity used in the United States, and therefore offers a large opportunity for savings. But, which energy-efficient lighting technology is the best choice?

In this paper:

- Life-cycle analysis (LCA) of energy-efficient lighting highlights that the usage phase of the lights dominates the lifetime energy consumption.
- Comparison of lighting efficiency needs to consider the applications, not simply the light sources.
- Today, light emitting diode (LED) lighting is the most efficient choice for a number of high-volume lighting applications.
- LED performance has improved rapidly and is expected to continue to outperform compact fluorescent lighting (CFL) technology by ever-widening margins.
- LED lighting does not contain harmful materials such as mercury.

LEDs: The Greenest Lighting Choice

Energy-efficient lighting technologies are available today that can enable us to drastically reduce the amount of electricity used in the United States. We face growing concerns about our traditional energy sources, related both to climate change and to the increasing cost, and it's critical that we accelerate the deployment of energy-efficient lighting to replace traditional energy-wasting light bulbs. The lighting industry and related individuals and organizations are engaged in a debate about the merits of LED lighting versus other energy-efficient lighting technologies such as CFL. Results from a number of recent studies show that LEDs are either the most efficient, greenest option or they are simply on par with the most efficient traditional lighting sources.

LEDs are the most efficient light source available today and they are also the greenest, containing no toxic mercury or lead. The confusion around LED lighting's declaration as the most efficient lighting source stems from the difference between traditional lighting sources – incandescent, halogen and fluorescent bulbs and tubes – and LEDs, commonly sold as light fixtures instead of bulbs. This has often led to comparing apples and oranges; that is lamp efficiency versus fixture (luminaire) efficiency.

Life Cycle Analysis

Both LED and CFL technologies offer energy-efficient alternatives to inefficient lighting technology such as incandescent bulbs. The U.S. Department of Energy has released an LCA of LED lighting and CFL conducted by Carnegie Mellon University's Green Design Institute and OSRAM Opto Semiconductors has completed an LCA study at the Siemens Corporate Technology Centre for Eco Innovations. LCAs track the entire life cycle, including the manufacturing process, the use phase, and

disposal at the end of life. Both the Carnegie Mellon and OSRAM studies found that production represents a relatively small portion of the total life-cycle impact for LED and CFL technologies. In both studies, total energy consumption is overwhelmingly due to usage. The LCAs find that 96 to 98 percent of the energy used is consumed to generate light and less than four percent is allocated to production.^{1, 2}

Lamp Efficiency: Critical for Saving Energy

Performance of LED products is projected to continuously improve, leading to rapidly rising efficacies. This rate of technology advancement requires diligence on the part of those conducting studies so that results accurately reflect state-of-the-art LED efficiencies as of the study date. When comparing LED lamps that produce about 60 lumens per watt (LPW) to CFLs, the results are very close (Figure 1 – Carnegie Mellon). LED technology is expected to continue to improve at a very fast pace, leading to an even greater energy disparity between LED products and CFLs.

Cree projects that the improvement in LED performance, measured by lumens-per-wafer, has and can be expected to continue to double every 18 to 24 months.

The two referenced LCAs show CFL and LED lighting (LED bulbs) to be roughly equivalent in terms of usage costs, though they do not consider the inherent improvements in lighting efficiency available with fixtures designed to use LEDs. Furthermore, consideration of the dominant lighting applications is needed to accurately reflect the environmental impacts.

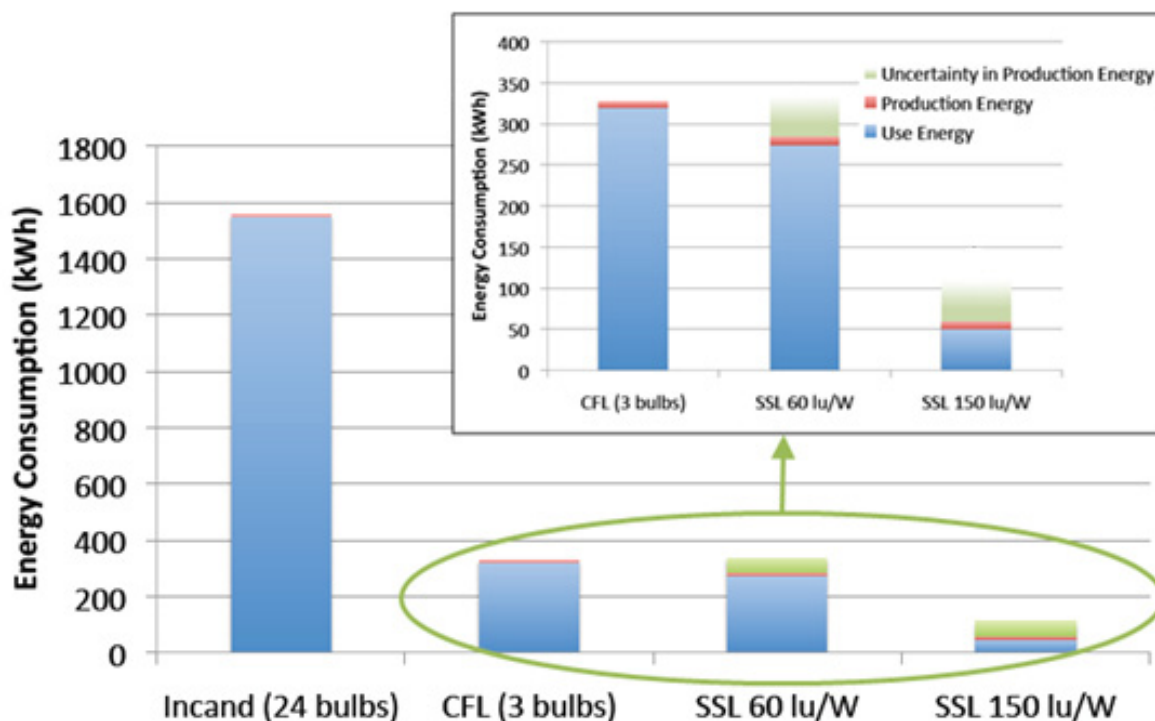


Figure 1: Comparison of the use phase and production energy consumption for various lighting technologies (Carnegie Mellon LCA). LED lighting at an efficacy of 60 lumens per watt has a comparable overall energy consumption to CFL.² With higher efficacy LED products, the total energy consumption will decrease further.

Lighting Application Matters: Downlights

Residential lighting typically accounts for 15 to 20 percent of U.S. household electricity use, composed of a mix of incandescent, fluorescent and compact fluorescent sources. Recessed downlights (can lights) comprise one of the fastest growing categories in residential applications and these types of lights are usually lit with inefficient incandescent or halogen bulbs. The U.S. Department of Energy estimates that more than 20 million downlights are sold in the U.S. each year and there are at least 500 million recessed downlights installed in U.S. homes.³ Recessed downlights – used widely for general ambient lighting in kitchens, hallways, bathrooms and other areas of the home – provide a significant energy savings opportunity.

In addition, recessed downlights are widely used in commercial installations such as hotels, retail stores and restaurants. In this application, incandescent and halogen sources are low cost and offer good color rendition and compatibility with the majority of installed controls, relative to the more efficient CFL lamps. LED sources have the potential for even longer life than CFLs, better light quality, good dimmability and more energy savings.

LEDs are a directional light source, emitting light in one direction as opposed to most incandescent, halogen, and fluorescent lamps which are omni-directional, emitting light – and heat – in all directions. For example, a CFL or incandescent bulb inside of a recessed can will waste about half of the light that it produces, while an LED recessed downlight only produces light where it's needed – in the room below. Because the light produced by LEDs is directional, they have a considerable advantage over other light sources for applications like recessed downlights or PAR-style spot lighting.

Cree's LR6 recessed downlight delivers typical efficacy of 62 LPW. Though CFL lamps offer similar efficacies to the LR6, a 10.5 W LR6 can replace a 26 W CFL in a six-inch can while providing the same amount of light.⁴ The source of this discrepancy can be found in what is known as "system efficacy."

A case study on LED downlights, performed by Sacramento Municipal Utility District, highlights the significance of system efficacy. In the example illustrated in Figure 2 below, the CFL lamp is rated at 50 LPW, though this rating does not take into account the fixture losses which may be up to 50 percent. Therefore, the system efficacy (delivered light) of the CFL fixture is only 25 LPW, compared to 54 LPW for the LR6 (this study was conducted with an earlier generation LR6 with a 12W rated load). The difference between lamp efficacy and system efficacy arises from the use of incandescent and CFL lamps in a variety of fixtures. Current industry practice is to measure the light output for lamps in an open air environment instead of the system efficacy of all possible fixtures using these types of lamps.

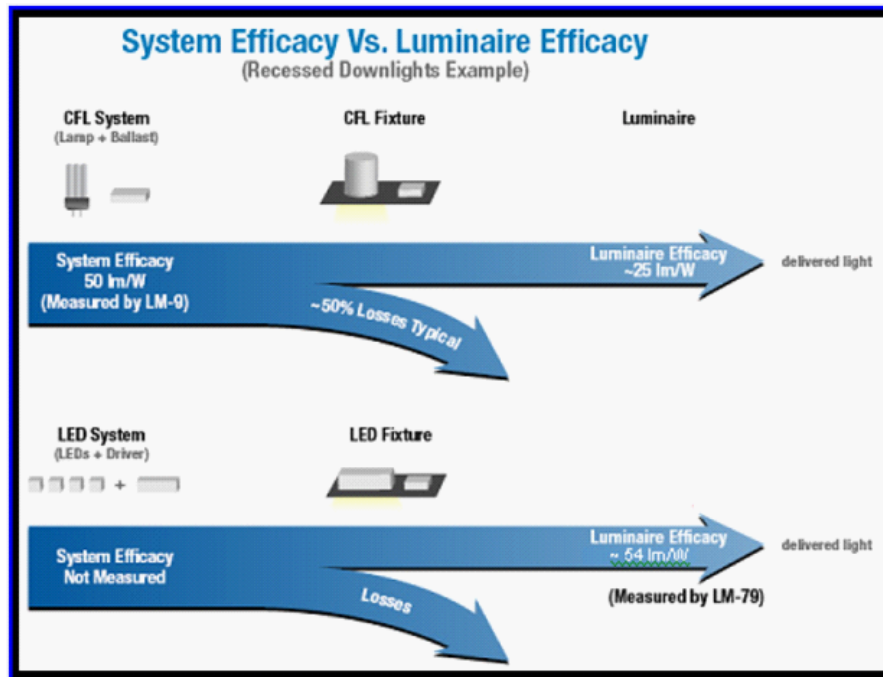


Figure 2: When comparing LEDs to other types of lighting systems, it is important to look at the total system efficacy – not just the efficacy of the light source (e.g. CFL bulb). The CFL fixture shown has losses of 50% (Sacramento Municipal Utility District case study). The amount of delivered light is only half of the light produced by the lamp.⁴ LEDs have a much lower fixture loss because they are highly directional, making them ideal for recessed downlights.

Other studies have benchmarked the performance of incandescent and CFL bulbs in downlight fixtures.⁵ Figure 3 shows an excerpt of the results of one such study for downlight applications. The directionality of LEDs allows a higher efficacy and superior energy savings over the traditional lighting technologies in a recessed can. LED downlights can surpass the efficacy of efficient lighting technology such as CFL by 65 to 100 percent in this application.

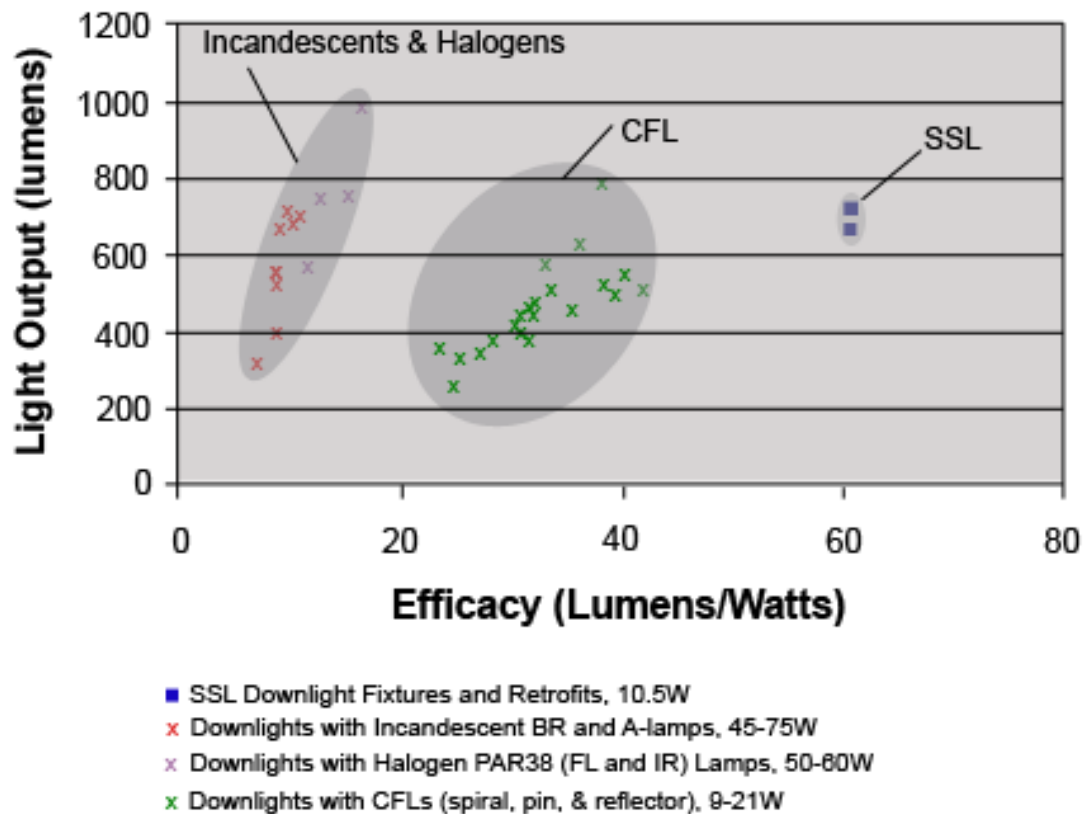


Figure 3: Comparison of various lighting technologies in a downlight application.

The Cree LR6 recessed downlight product was initially released in 2007 with a performance of 54 LPW and a projected lifetime of 50,000 hours. Over the past two years, rapid advancements in LED technology have led to a prototype LR6 High-Efficiency (HE) downlight demonstrating 102 LPW – providing 665 lumens at a mere 6.5W of electricity.⁶ This increased performance will lead to even greater energy savings over the life-cycle of the LED lighting product compared to incandescent and fluorescent lighting.

A lifetime energy usage comparison between a typical CFL recessed downlight and the Cree LR6 is shown in Figure 4 below.

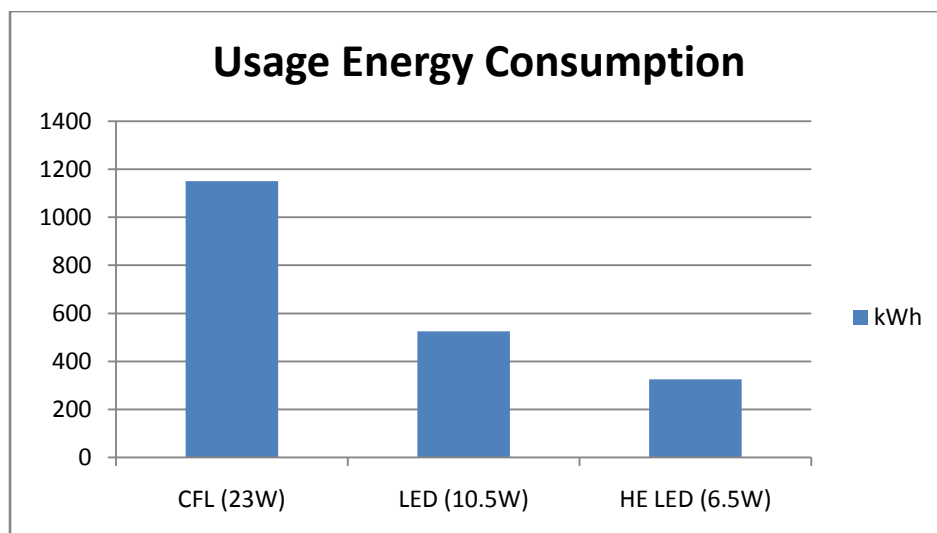


Figure 4: Comparison of CFL to Cree LR6 LED and High-Efficiency LR6 LED lifetime energy usage in a recessed downlight application (50,000 hours at equivalent lumens output).

Spot Lighting

Narrow beam PAR38 spotlights are used in many display applications, such as supermarket produce displays, department stores, and museums—especially where exceptional color quality is valued. These lights are typically halogen lamps, although compact fluorescent lamps are being used where a more energy-efficient solution is desired.

In May of 2009, Cree introduced the LRP 38, an LED retrofit lamp designed to replace halogen and compact fluorescent PAR38 lamps. The LRP 38 lamp provides a tightly-focused beam with exceptional color quality, extended lifetime and energy-efficiency.⁷ The LRP-38 is much more energy efficient than halogen sources (12W vs. 50W+) and also more efficient than alternative technologies such as compact fluorescent lamps (12W vs. 23W). Moreover, the high color rendition, beam control, long lifetimes, absence of mercury and low heat, infrared and ultraviolet emissions make it a clear choice for many applications.

As with recessed downlights, the life-cycle impact for spotlights is also dominated by the energy consumed during the usage lifetime of the lamps. A comparison of halogen, compact fluorescent and LED lamp usage energy is shown below in Figure 5.

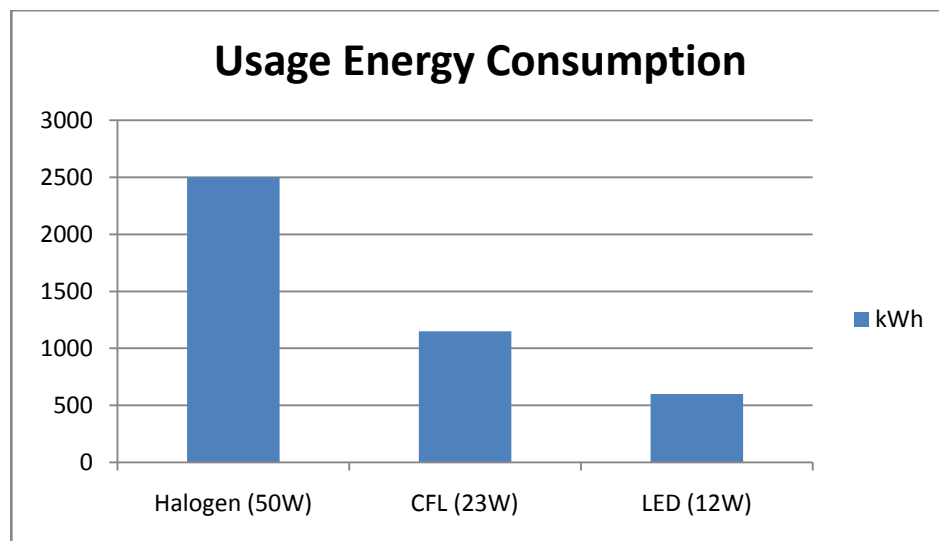


Figure 5: Comparison of lifetime energy usage in a PAR38 spot application (50,000 hours at equivalent lumens output).

Summary

LED lighting products are now more efficient than traditional lighting technologies when compared across the high-volume applications of recessed downlighting and display spotlighting. Moreover, LED technology is projected to advance at a rapid rate, increasing the gap between it and traditional lighting. The life-cycle energy comparisons for these applications demonstrate that LEDs offer clear advantages in terms of energy costs and environmental impact.

References

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⁵ DOE Solid-State Lighting CALiPER Program: Summary of Results: Round 4 of Product Testing; CALiPER Summary Report, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, January 2008.

⁶ Cree Demonstrates Prototype LR6 LED Downlight with 102 Lumens per Watt Fixture Efficacy; Cree Inc. Company Press Release, May 5, 2009.

⁷ Cree Announces Best-in-Industry PAR 38 LED Bulb; Cree Inc. Company Press Release, April 28, 2009.