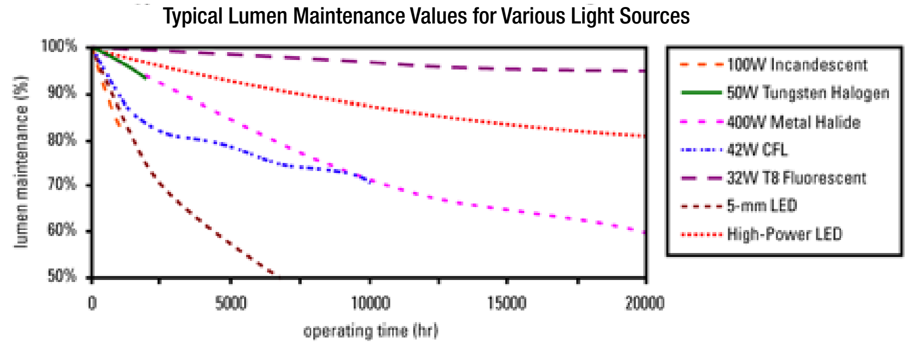
# Lifetime of White LEDs

**One of the main "selling points" of LEDs is their potentially very long life. Do they really last 50,000 hours or even 100,000 hours? This fact sheet discusses lumen depreciation, measurement of LED useful life, and the features to look for in evaluating LED products.**

## Lumen Depreciation

All electric light sources experience a decrease in the amount of light they emit over time, a process known as lumen depreciation. Incandescent filaments evaporate over time and the tungsten particles collect on the bulb wall. This typically results in 10-15% depreciation compared to initial lumen output over the 1,000 hour life of an incandescent lamp.

In fluorescent lamps, photochemical degradation of the phosphor coating and accumulation of light-absorbing deposits cause lumen depreciation. Compact fluorescent lamps (CFLs) generally lose no more than 20% of initial lumens over their 10,000 hour life. High-quality linear fluorescent lamps (T8 and T5) using rare earth phosphors will lose only about 5% of initial lumens at 20,000 hours of operation. The primary cause of LED lumen depreciation is heat generated at the LED junction.




*Source:* Adapted from Bullough, JD. 2003. *Lighting Answers: LED Lighting Systems.* Troy, NY. National Lighting Product Information Program, Lighting Research Center, Rensselaer Polytechnic Institute.

LEDs do not emit heat as infrared radiation (IR), so the heat must be removed from the device by conduction or convection. Without adequate heat sinking or ventilation, the device temperature will rise, resulting in lower light output. While the effects of short-term exposure to high temperatures can be reversed, continuous high temperature operation will cause permanent reduction in light output. LEDs may continue to operate even after their light output has decreased to very low levels. This becomes an important factor in determining the effective useful life of the LED.

## Defining LED Useful Life

To provide an appropriate measure of useful life of an LED, a level of acceptable lumen depreciation must be chosen. At what point is the light level no longer meeting the needs of the application? The answer may differ depending on the application of the product. For a common application such as general lighting in an office environment, research has shown that the majority of occupants in a space will accept light level reductions of up to 30% with little notice, particularly if the reduction is gradual.[1] Therefore a level of 70% of initial light level could be considered an appropriate threshold of useful life for general lighting. Based on this research, the Alliance for Solid State Illumination Systems and Technologies (ASSIST), a group led by the Lighting Research Center (LRC), recommends defining useful life as the point at which light output has declined to 70% of initial lumens (abbreviated as $L_{70}$) for general lighting and 50% ($L_{50}$) for LEDs used for decorative purposes. For some applications, a level higher than 70% may be required.

[1]Rea MS (ed.). 2000. IESNA Lighting Handbook: Reference and Application, 9th ed. New York: Illuminating Engineering Society of North America. Knau H. 2000. Thresholds for detecting slowly changing Ganzfeld luminances. J Opt Soc Am A 17(8): 1382-1387.

*OSRAM Opto Semiconductors Photo credit: OSTAR™ Lighting*

## Terms

**Lumen depreciation** – the decrease in lumen output that occurs as a lamp is operated.

**Rated lamp life** – the life value assigned to a particular type lamp. This is commonly a statistically determined estimate of average or median operational life. For certain lamp types other criteria than failure to light can be used; for example, the life can be based on the average time until the lamp type produces a given fraction of initial luminous flux.

**Life performance curve** – a curve that presents the variation of a particular characteristic of a light source (such as luminous flux, intensity, etc.) throughout the life of the source. Also called lumen maintenance curve.

## Checklist

What features should you look for in evaluating the projected lifetime of LED products?

- ☑ Does the LED manufacturer publish thermal design guidance?
- ☑ Does the LED manufacturer have LM-80 lumen maintenance data?
- ☑ Does the lamp design have any special features for heat sinking/thermal management?
- ☑ Does the fixture manufacturer have test data supporting life claims?
- ☑ What life rating methodology was used?
- ☑ What warranty is offered by the manufacturer?

## Measuring Light Source Life

The lifetimes of traditional light sources are rated through established test procedures. For example, CFLs are tested according to LM-65, published by the Illuminating Engineering Society of North America (IESNA). A statistically valid sample of lamps is tested at an ambient temperature of 25° Celsius using an operating cycle of 3 hours ON and 20 minutes OFF. The point at which half the lamps in the sample have failed is the rated average life for that lamp. For 10,000 hour lamps, this process takes about 15 months.

Full life testing for LEDs is impractical due to the long expected lifetimes. Switching is not a determining factor in LED life, so there is no need for the on-off cycling used with other light sources. But even with 24/7 operation, testing a LED for 50,000 hours would take 5.7 years. Because the technology continues to develop and evolve so quickly, products would be obsolete by the time they finished life testing.

The IESNA has developed a procedure (IES LM-80) for measurement of lumen maintenance for LED devices (e.g., LED packages, arrays, modules); however, this method does not cover LED luminaires or integral replacement lamps. LM-80 also does not provide guidance for estimating or extrapolating lumen maintenance beyond the 6,000 hour measurement period prescribed in the test method. To address long-term performance of LED products, the IESNA is currently developing a companion estimation method (IES TM-21) to estimate LED lumen maintenance and service life beyond 6,000 hours. TM-21 will utilize LM-80 data collected at multiple operating temperatures. Because of their potentially long life and impracticality of complete testing, estimates of the life of LEDs will likely be based on the extrapolation of limited test data. It is, therefore, important at this technology's early stage to be conservative in design decisions based on expected useful life.

### *LED Lifetime Characteristics*

How do the lifetime projections for today's white LEDs compare to traditional light sources?

| Light Source | Range of Typical Rated Life (hours)* (varies by specific lamp type) | Estimated Useful Life ($L_{70}$) |
|---|---|---|
| Incandescent | 750-2,000 | |
| Halogen incandescent | 3,000-4,000 | |
| Compact fluorescent (CFL) | 8,000-10,000 | |
| Metal halide | 7,500-20,000 | |
| Linear fluorescent | 20,000-30,000 | |
| High-Power White LED | | 35,000-50,000** |

*Source: lamp manufacturer data.

**Depending on drive current, operating temperature, etc. some manufacturers are claiming useful life (L70) values greater than 100,000 hours.

Electrical and thermal design of the LED system or fixture determine how long LEDs will last and how much light they will provide. Driving the LED at higher than rated current will increase relative light output but decrease useful life. Operating the LED at higher than design temperature will also decrease useful life significantly.

Most manufacturers of high-power white LEDs estimate a lifetime of around 30,000 hours to the 70% lumen maintenance level, assuming operation at 350 milliamps (mA) constant current and maintaining junction temperature at no higher than 90°C. However, the thermal robustness of LEDs continues to improve, allowing for higher drive currents and higher operating temperatures. For example, the latest high power white LED packages claim a lifetime of 50,000 hours to the 70% lumen maintenance level, when operated at 700 milliamps (mA) constant current or higher, and even at maintained junction temperatures exceeding 100°C.

### A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, a cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

### For more information contact:

EERE Information Center
1-877-EERE-INF
(1-877-337-3463)
www.eere.energy.gov

### For Program Information on the Web:

www.ssl.energy.gov
DOE sponsors a comprehensive program of SSL research, development, and commercialization.

### For Program Information:

**Robert Lingard**
Pacific Northwest National Laboratory
Phone: (503) 417-7542
E-mail: robert.lingard@pnl.gov

**PNNL-SA-50957**
**September 2009**

Printed on 30% post-consumer recycled paper.