Carnegie Mellon — Civil and Environmental Engineering

Life Cycle Energy Consumption of Solid State Lighting Products

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Background

Lighting constitutes approximately 12 percent of residential and 25 percent of commercial building energy consumption. To reduce energy consumption from lighting appliances, decades of energy efficiency programs have focused on improving lighting technologies.

Solid-state lighting (SSL) refers to a type of lighting that uses light-emitting diodes (LEDs), organic light-emitting diodes (OLED), or polymer light-emitting diodes (PLED) as sources of illumination. Unlike incandescent or fluorescent lamps, which create light with filaments and gases encased in a glass bulb, solid-state lighting consists of semiconductors that convert electricity into light. SSL systems are an energy efficient lighting option that is increasingly used in a variety of applications. Luminous efficacy is used to assess the energy efficiency of light sources and is typically measured in lumens per watt (lm/W). Long-term research and development projections call for white-light LEDs producing 160 lm/W by 2015, while traditional incandescent and fluorescent lamps only produce 15 lm/W and 60 lm/W respectively. Therefore, commercial SSL products have the potential to dramatically reduce lighting energy consumption.

However, even though SSL products offer great energy savings during use, their net energy consumption over the life cycle is of concern. The final SSL product is more complex compared to an incandescent or compact fluorescent lamp (CFL), and includes components that potentially require more energy consumption. The two main components in a SSL bulb are the LED package, the light source, and the luminaire which includes the remaining lamp functions to distribute the light, and to connect, position, and protect the light source. Both the LED package and the luminaire host a variety of energy use concerns. The high purity of materials and processing used for the LED package, and the large mass of heat sink used in the luminaire are among the main energy consumption concerns for each component.

Therefore, it is necessary to investigate the energy consumption of the entire SSL product life cycle while focusing on the following phases: Raw material extraction, materials and parts manufacturing, product manufacturing, use and end-of-life.

Future Work

Our research focus is to:

1) Compare energy use of current SSL technology to existing incandescent and CFL technologies over the life cycle.
2) Identify whether the SSL life cycle incorporates any materials that may pose a threat to human health.
3) Estimate the lifetime for the various SSL product components to determine any limitations to bulb life.
4) Determine recycling and reverse logistics for material recovery in SSL products.

LED Package

LED Luminaire

Photo Source: Cree, Journee

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