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REPORT IN BRIEF

Assessment of Advanced Solid State Lighting

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The standard incandescent light bulb, which still works mainly as Thomas Edison invented it, converts more than 90% of the consumed electricity into heat. Given the availability of newer lighting technologies that convert a greater percentage of electricity into useful light, there is potential to decrease the amount of energy used for lighting in both commercial and residential applications. Although technologies such as compact fluorescent lamps (CFLs) have emerged in the past few decades and will help achieve the goal of increased energy efficiency, solid state lighting (SSL) stands to play a large role in dramatically decreasing U.S. energy consumption for lighting. This report summarizes the current status of SSL technologies and products—light-emitting diodes (LEDs) and organic LEDs (OLEDs)—and evaluates barriers to their improved cost and performance. It also discusses factors involved in achieving widespread deployment and consumer acceptance of SSL products. These factors include the perceived quality of light emitted by SSL devices, ease of use and the useful lifetime of these devices, issues of initial high cost, and possible benefits of reduced energy consumption.

Study Background

General lighting for illumination consumes approximately 20% of electricity generated and sold in the United States. Congress recognized the potential for energy savings in the lighting sector in the Energy Independence and Security Act of 2007 (EISA 07), which mandates higher efficacy in general lighting according to a set of targets and timetables. Congress requested that the Department of Energy (DOE) contract with the National Research Council (NRC) to conduct a study to assess the status of SSL as a technology and provide a review of the development of SSL technology and products, a discussion of future impacts, and an analysis of the implications of the study's findings for decision making.

The full NRC report suggests that lighting products based on LEDs will be able to support the required lumen output standards as mandated in EISA 07. The report also considers market penetration of the SSL products and evaluates the likely impacts on energy use that may result from the deployment of SSL lighting products, taking into account the effect of the lumen output standards on the market for conventional light sources.

Introduction to SSL Technologies

There are two types of SSL technologies: the inorganic semiconductor-based LED and the polymeric-based OLED. Both technologies are the subject of active research worldwide. LED technology is currently in the early stages of commercial deployment, while OLEDs are in the demonstration phase. LED-based lighting products are available in two forms. The first consists of light bulbs—referred to as "lamps"—that can replace, one-for-one, an existing lamp without modification to the original luminaire, commonly known as the fixture. The second product is the purpose-built luminaire, which has either an integral LED light source or an LED module that can be removed. To be retrofit, these would require complete removal and replacement of the luminaire.

When replacing incandescent or fluorescent lamps, LED lamps provide an opportunity for greatly reducing power load and increasing lamp life. Compared with commonly used fluorescent lamps— including CFLs, which have served as screw-in replacements for incandescent bulbs, or the older T12 linear fluorescent tubes—LED lamps will have cheaper lifecycle costs in the near future as the technology improves.

Barriers to Widespread Deployment

Consumer Acceptance

Consumer acceptance of SSL will depend on an understanding of its unique characteristics. Americans are used to purchasing their lamps as a function of the rating in watts, a unit denoting the rate at which energy is consumed. Intuitively, most people understand how much light a 40-watt incandescent lamp provides compared to a 60-watt or 75-watt lamp. As the technological options for lighting shift away from the incandescent lamp to more energy efficient alternatives such as CFLs and LEDs, the basic terms used for lighting discussions also need to change. Instead of thinking in terms of watts, consumers now need to learn a measurement system that tells them how much light a product is going to emit—measured in lumens, this unit can either be described in absolute terms or, as in the case of a lamp's efficacy, per unit of power consumed (lumens/watts). And this is just the beginning of the changes that consumers are likely to see if LED and OLED lighting continue to improve at their current rates.

Consumers will need to evaluate many attributes of SSL products—for luminous output (lumens), power (watts), efficacy (lumens/watt) and the quality of light—if they are considering a transition to LEDs for home lighting. It is more likely that they will choose the latter in the future, particularly as the final stages in the timetable for new lighting efficiency standards takes effect in 2014. There is additional key information beyond what is given in the lamp specifications that could affect consumer preferences. These include, for example, the lamp's or luminaire's dimming capability and estimated lifetime. The report recommends that DOE, lamp manufacturers, and retailers work together to ensure that consumers are educated about the characteristics and metrics of these new technology options. The market for these lamps will only expand as the light and color quality improves and the costs are reduced.

Cost

Even though it is likely that use of SSL products will lead to reduced energy consumption, factors such as system life, lamp-to-lamp color variation, glare, flicker, and dimming can, if they do not meet user expectations, lead to slower market adoption. Integral LED replacement lamps and retrofit luminaires have higher initial costs than today's competing technologies. The high initial cost in some LED products relative to conventional light sources is due to a combination of costs associated with the LED device, heat sink, electronics, and packaging. All categories of cost will need to be addressed along the value chain to improve the quality of light, product life, and overall lifecycle cost compared to current lighting products on the market.

Increasing efficacy not only improves energy savings but has a strong leveraging effect on the cost of LED lamps and luminaires as well. This is because, as less heat is generated, smaller and less complicated thermal management and packaging systems are required. Addressing the problem of thermal management is challenging because of the need to maintain the temperature of the LED chip below 200°C. The small size of the chip has the consequence that, if adequate heat sinking is not provided, even a watt or two of dissipation will raise its temperature well beyond this limit.

The report recommends that DOE continue to make investments in LED core technology, aimed at increasing yields, and in fundamental emitter research aimed at increasing efficacy. This includes improvements in the controlled growth and performance of the emitter material.

Committee on Assessment of Solid State Lighting: John Kassakian, Chair, Massachusetts Institute of Technology; **Inês Azevedo,** Carnegie Mellon University; **Nancy E. Clanton,** Clanton & Associates; **Wendy Davis,** University of Sydney; **Paul A. Decotis,** Long Island Power Authority; **Steven P. Denbaars,** University of California, Santa Barbara; **Michael Ettenberg,** Dolce Technologies; **Stephen Forrest,** University of Michigan; **Pekka Hakkarainen,** Lutron Electronics; **Evelyn Hu,** Harvard University; **Gary Marchant,** Arizona State University; **Nadarajah Narendran,** Rensselaer Polytechnic Institute; **Maxine Savitz,** Honeywell, Inc. (retired); **Michael G. Spencer,** Cornell University

Staff: Jonna Hamilton, Study Director (through December 2011); **Martin Offutt,** Study Director (from December 2011); **James Zucchetto,** Director, Board on Energy and Environmental Systems; **David Cooke,** Research Associate, Board on Energy and Environmental Systems; **LaNita Jones,** Administrative Coordinator, Board on Energy and Environmental Systems; **Alice Williams,** Senior Project Assistant, Board on Energy and Environmental Systems; **E. Jonathan Yanger,** Senior Program Assistant, Board on Energy and Environmental Systems

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