An Introduction to Solid State Lighting

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Unlike the incandescent / fluorescent lamp world of today’s electrical lighting fixtures, solid-state lighting is in the realm of electronics with multiple interdependent ancillary systems. The purpose of this series of articles is to provide an informative summary of the elements that comprise these new electronic systems and to introduce a holistic new systems approach to the design and manufacturing of SSL fixtures.

The ability to keep up with the increasing need for electrical energy is causing a global pull towards more energy-efficient products. Lighting consumes over 25% of the electricity generated in the United States. Most industrial nations have a similar high percentage of energy production consumed by lighting.

The most energy-efficient lighting products use light-emitting diode (LED) technology (Figure 1). These solid-state lighting (SSL) products are more expensive today than the next best energy efficient alternative. However, ongoing development is rapidly improving SSL capability and cost-effectiveness. If all lighting was shifted to SSL, it would reduce the lighting energy consumption to less than 10% of electricity generated.

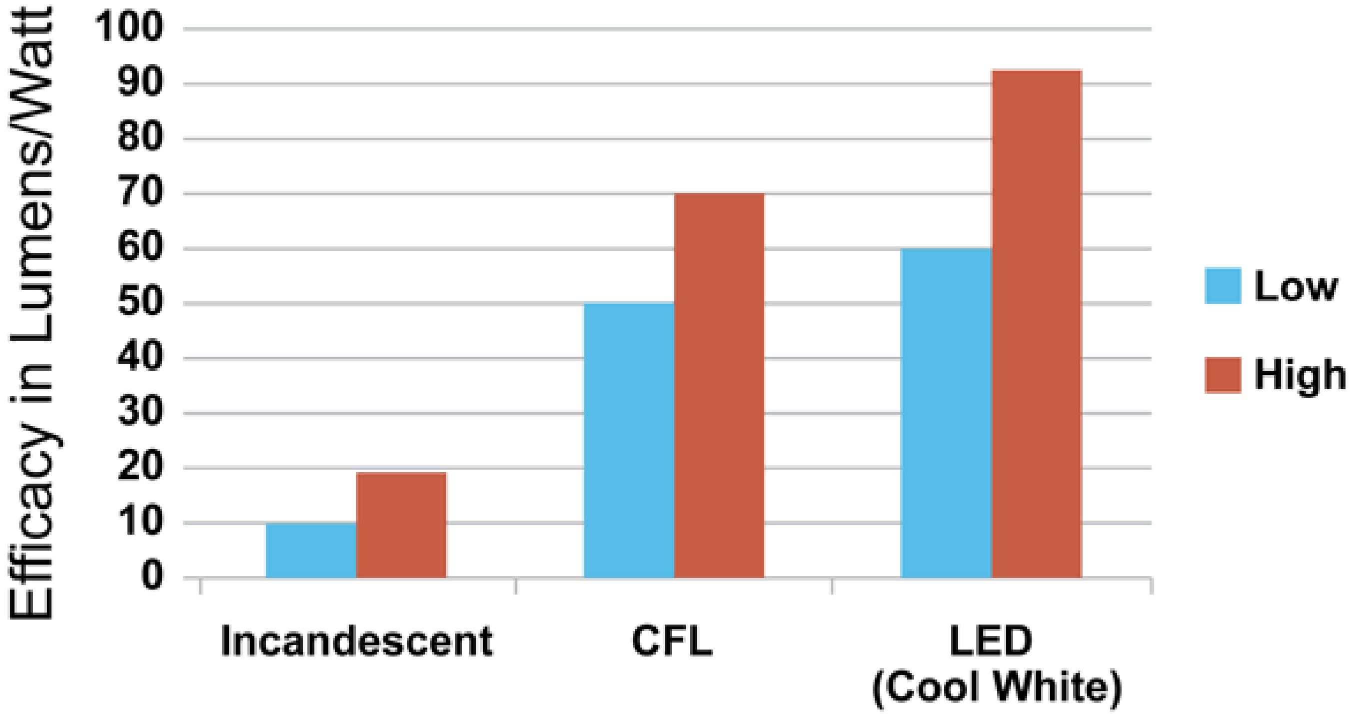

Figure 1. The Efficiency of Traditional Light Sources Compared to Solid-State Lighting Shows the Significant Benefit of LED-based SSL. (Source: Department of Energy (DOE) Energy Savers)

Why Solid State Lighting is Important
In 2009, the lighting industry generated sales of $75 billion globally with less than 5% being solid-state lighting. However, more efficient solid-state products are poised to grow rapidly. Sales of new and retrofit SSL fixtures are projected to increase to over half of the $91 billion in lighting sales in 2014 and further rise to 75% market share by 2019. Regulations coupled with higher energy cost and lower SSL costs will dictate the pace of this change. Governments most aggressively pursuing the elimination of incandescent bulbs include those in the European Union, Japan, United States, Canada, Australia and the Republic of China.

In 2009, restrictions on the sale of incandescent bulbs began in most of Europe based on Directive 2005/32/Ec of The European Parliament and of the Council of 6 July 2005. Australia was the first country to announce a ban for incandescent bulbs. The ban went into effect in 2010. Canada was the second country to announce an incandescent bulb ban that goes into effect in 2012.

The Japanese government implemented a series of subsidy policies to pursue the commitment it made in the Kyoto Protocol. In December 2006 the JELMA (Japan Electric Lamp Manufacturers Association) announced four proposals to substitute less efficient lamps with higher efficiency alternatives. On April 5, 2008, the Minister of the Ministry of Economy, Trade and Industry (METI) announced “the replacement policy for Incandescent to CFLi by 2012”.

An energy bill passed in 2007 by the U.S. Congress, the Energy Independence and Security Act of 2007, effectively bans the incandescent light bulb as we know it by

2014. Initially, the conventional 100-watt bulb will be discontinued in 2012. The incandescent light phase-out process ends with the elimination of 40-watt bulbs in 2014. The actual requirement is for all light bulbs to consume 25 to 30% less energy by 2014 and 70% less by 2020. Since incandescent bulbs waste about 90% of their input energy on heat, this eliminates them as a viable lighting contender after 2014. High-efficiency incandescent light bulbs are being pursued that may extend a small portion of the incandescent market but their cost is quite high. California Title 24 has established energy standards for residential and nonresidential buildings that are dictating energy standards for the rest of the country.

With the world's supply of non-renewable energy from fossil fuels depleting rapidly, the need to reduce energy consumption is a global imperative. Developing countries want to experience the same advantages that developed countries have enjoyed. However, developed countries have shown that the insatiable demand for energy-hungry products has exceeded their capacity to generate sufficient energy to support them, especially when the energy must come from clean energy sources. China has announced plans to phase out incandescent bulbs that could be completed by 2017.

Without the increased implementation of energy efficient alternatives, the insatiable demand for more electrical energy can only be solved by building more electrical power plants. Unfortunately, it takes about 10 years to build a plant in the US to provide additional power generating capacity. In the U.S., the projected increase in demand of 135,000 megawatts versus the projected additional capacity of 77,000 megawatts results in a shortfall of 58,000 megawatts. [Data courtesy of NERAC.] As a result, subsidizing more efficient technology is a preferred alternative. Prof. Michael Siminovitch, Director of the California LightingTechnology Center notes that, "Solid state lighting equipment provides significant long-term energy savings and is much less costly to buy than the generating facilities used to provide power for ordinary wasteful lighting fixtures. As a result, utilities, federal and state governments are providing an ever widening array of utility incentives for the adoption of solid state lighting devices."

Initially, compact fluorescent lighting was the solution to improved efficiency and replacement of incandescent bulbs because of its lower cost. However, CFLs contain mercury and, as such, create a hazardous waste condition when they are discarded. In contrast, LEDs do not contain hazardous materials and products can be disposed of without concern.

LED technology is improving rapidly. Haitz's Law predicts "that every decade, the cost per lumen (unit of useful light emitted) falls by a factor of 10 and the amount of light generated per LED package increases by a factor of 20." The improvements made over the last 30 years of the twentieth century (Figure 2) have continued into the 21st century. As cost-effective lighting evolves, any company or individual with a stake in the future of the lighting industry should be intimately aware of LED-based lighting's current status and progress toward becoming the dominant lighting source for residential, commercial and industrial lighting.

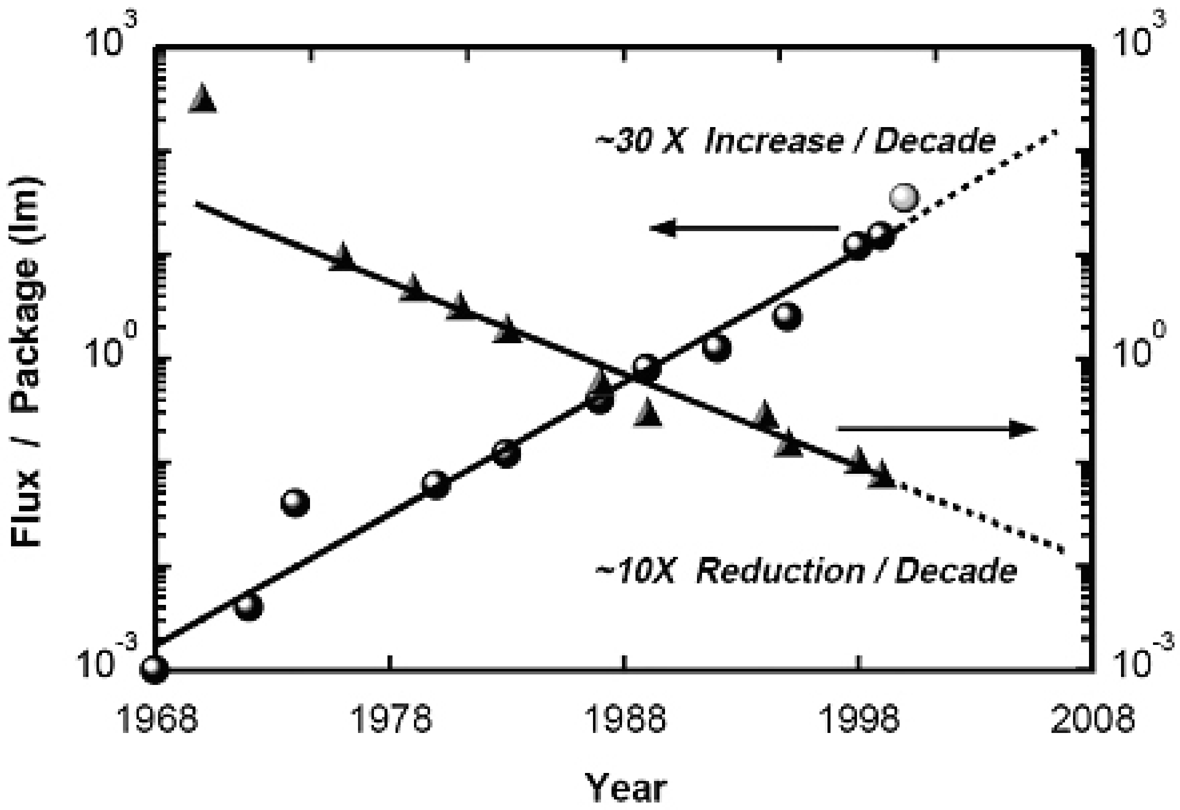

Figure 2. According to Haitz's Law, the Amount of Light Generated per LED Package will Predictably Increase and the Cost/Lumen of Light Will Predictably Decrease Each Decade. (Source: The Case for a National Research Program on Semiconductor Lighting)

The rapid improvements in LED technology that fulfill Haitz's Law have generated recent SSL growth that is attributable to compelling applications that are emerging for solid state lighting such as commercial refrigeration and street lighting. Commercial refrigeration lighting is a perfect application for LEDs. This very cold environment typically has the lighting on continuously. The longer life expectancy of LEDs makes them a natural for avoiding frequent bulb replacement. In addition, LEDs function better at lower temperatures compared to fluorescent bulbs that have to be overdriven and start to lose arc requiring an increasing amount of energy. This requires the refrigeration units to expend even more energy to overcome the increased heat generated by the lighting.

For street lighting and in many industrial and consumer applications, the maintenance avoidance issue alone is sufficient to warrant the use of solid state lighting. The cost to replace a bulb in some environments is as high as $200/hour and that does not include the disruption (loss of sales) for shoppers in commercial environments or loss of productivity in industrial situations. As early adopters take advantage of the unique capabilities of SSLs and Haitz's Law continues its downward trend, the technology will expand to broader applications.

The Transition to Solid State Lighting
As in many other industries, consumers expect the leading technology companies to respond to global imperatives with new products that use the latest technologies.

Solid state lighting is and has been promoted as the solution for improved efficiency and leading companies need to deliver on this promise. However, certain aspects such as cost and complexity have limited the industry’s response.

Lighting suppliers have closely monitored how poorly the transition from incandescent lighting to the obviously more efficient compact fluorescent lamp (CFL) technology has been handled. The lessons learned from this process are being applied to solid state lighting. Among the key observations is the difficulty suppliers have had in coping with a new technology. SSL is even more complex than CFL, so a new approach is required.

Design Issues

Complete solid state lighting solutions involve technical expertise in myriad technologies. As shown in Figure 3, several distinct, high-level areas are easily identified. Knowledge in one area can be quite unique and the successful application of that know-how must be brought together at the systems level to achieve an optimum lighting solution that takes into account the interaction between the technologies. The number of different areas of expertise required and the interaction between them has been among the factors that have hindered the development of solid state lighting. (Each of these areas will be discussed in detail in subsequent installments of this article series.)

Figure 3. Several essential and interconnected technology areas of Solid State Lighting (SSL) must be brought together at the systems level for a successful SSL solution. (the SSL orbit: courtesy of Tyco Electronics).

Regulatory Issues
In addition to existing lighting standards and regulatory issues, solid state lighting represents a dynamic area where standards are changing and new standards are being issued on a continuous basis. Several regulatory agencies have already modified or established requirements for solid state lighting.

These standards address performance, radio frequency emission/interference, testing, safety and other issues. For example, Underwriters Laboratories Inc. (UL) Class 2 Power Units (UL 1310) and Light-Emitting Diode (LED) Light Sources for Use in Lighting Products (UL 8750) have recently been issued. The International Electrotechnical Commission (IEC), a worldwide organization for standardization, has previously established lighting requirements for luminaires. Other regulatory and standards organizations that impact solid state lighting include:

• American National Standards Institute (ANSI) / National Electrical Manufacturers Association (NEMA) efforts include industry norms, guidelines and standards for SSL products.
• Illuminating Engineering Society of North (IESNA) is the recognized North American technical authority on illumination and currently publishes LM-79 and LM-80 SSL standards. IESNA is developing a specification (EN 21) for long term reliability of fixtures.
• IESNA has partnered with American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) to develop efficient lighting for buildings. ASHRAE has a lighting subcommittee that generates standards.
• International Commission on Illumination (CIE) has several standards for lighting performance including SSL.
• Federal Communications Commission (FCC) is involved with radio frequency aspects of SSL.
• Federal Trade Commission (FTC) is pursuing more accurate labeling for light bulbs.
• Department of Energy (DOE) Commercially Available LED Product Evaluation and Reporting (CALiPER) program tests and reports on available SSL products.
• Environmental Protection Agency (EPA) has the ENERGY STAR qualified LED lighting.

This is actually a rather short (and by no means complete) summary of what is occurring today in the area of SSL regulations and standards. In a few years, the list will be completely different. While light fixture suppliers may be well aware of and readily capable of dealing with traditional and even fluorescent lighting regulations, meeting any one of these and other organizations' new requirements for solid state lighting can prove to be a challenge. Complying with all of them, especially in a coordinated, harmonized manner could be a daunting task and provide a considerable delay to market entry. For example, the ENERGY STAR Solid State Lighting (SSL) Luminaire program went into effect on September 30, 2008. Warranty is one of the requirements for ENERGY STAR conformance. Unlike conventional lighting that has a typical 90-day warranty, ENERGY STAR requires a three year warranty that is expected to increase to five years in the near future. An enhanced and expanded version is in the final comment phase before its publication.

In addition to lighting-specific changes, the difference in lighting design requirements for SSLs (DC instead of AC) may eventually change the way that buildings are wired. For example, 24 VDC could become a standard for distributed lighting within buildings. For this to happen, significant changes and modifications to building codes will have to occur. Leading LED and SSL suppliers will be intimately involved in and well aware of the changes that could occur long before they are implemented.

This article is excerpted from a white paper entitled “A Systems Approach to the Design and Manufacture of Solid State Lighting Fixtures” available for download at www.nevalo.com [1]

Links:
[1] http://www.nevalo.com