NOVEMBER/DECEMBER 2010

LEDs MAGAZINE

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TECHNOLOGY AND APPLICATIONS OF LIGHT EMITTING DIODES

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LEDs light up LA P.37

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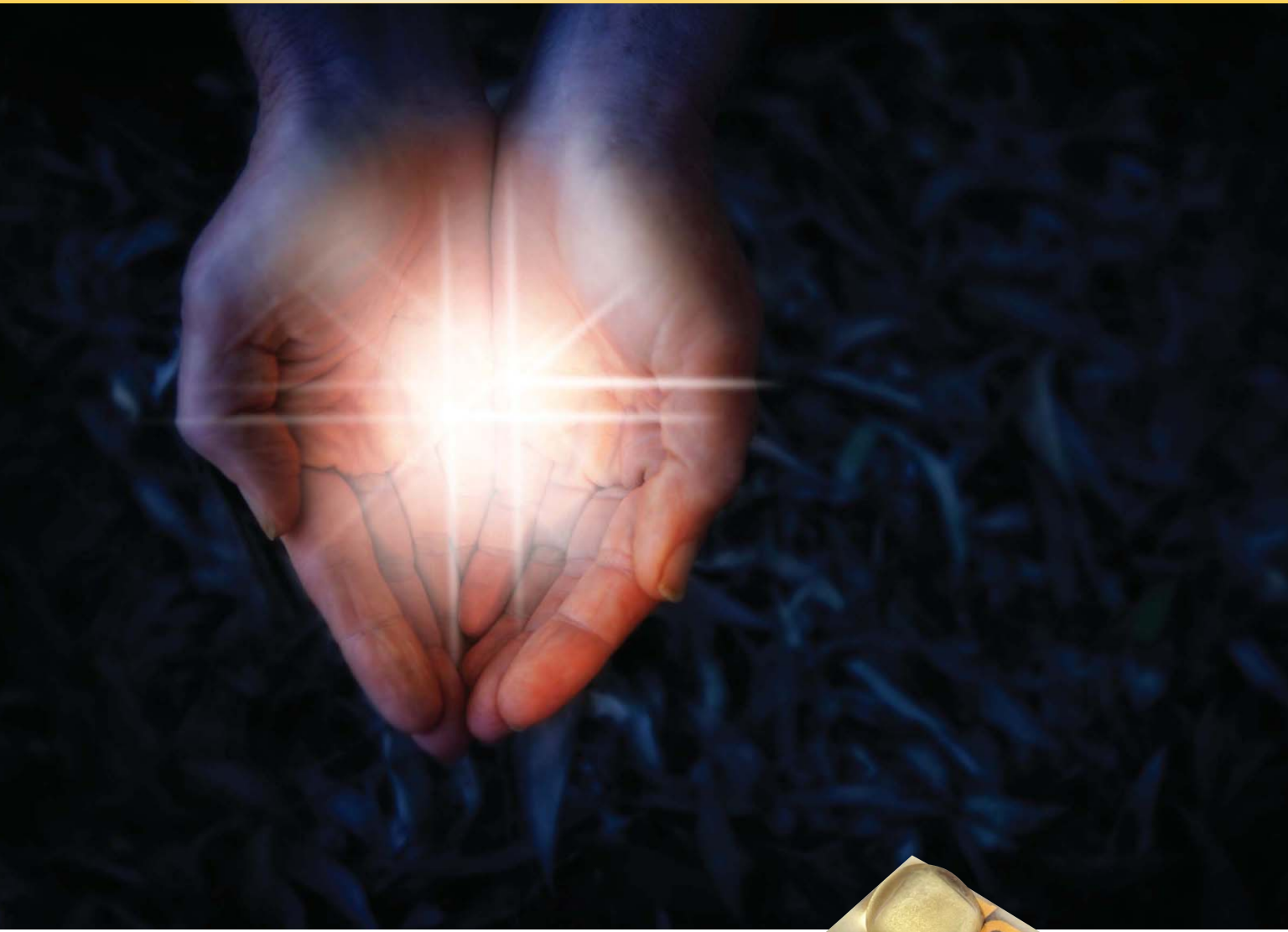

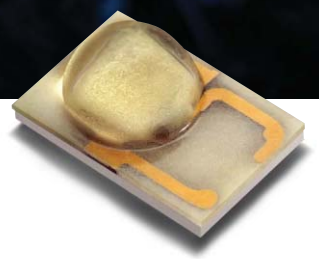

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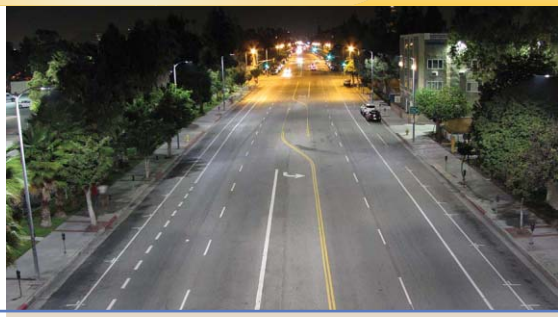

Cover Story

This image, courtesy of the Bureau of Street Lighting, City of Los Angeles, shows some of the 140,000 LED outdoor lighting fixtures that will eventually be installed in the city (see page 37).

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commentary

Outdoor SSL outpaces standards and practices

I just attended the Illuminating Engineering Society (IES) Street and Area Lighting Conference (SALC) for the first time. In some ways the event mirrored other recent LED and lighting conferences – LED-based solid-state lighting (SSL) was the star of the show (see p.37). But there was a mixed climate in feelings among the crowd somewhat like the hot sunshine that was prevalent on Monday that gave way to the costal marine layer later in the week. Despite the promise of LEDs there are legacy standards and practices, and logistical issues like utility tariffs, that may significantly slow the adoption of SSL technology.

Leading up to SALC, I doubted that anything could hold SSL back in an application such as street lighting where LEDs offer key advantages in energy efficiency, dimming capabilities, and long life. Some SALC presentations made me wonder if the technology will get a fair chance to shine given the standard and tariff issues that are impacting payback periods.

Today, the cost premium associated with installing LEDs is being covered by grants – especially in the US with the American Recovery and Reinvestment Act. But those grants won't last forever, and municipalities need the ability to project realistic payback periods on real purchases to justify LED installations.

The LED and luminaire industry is doing its part to drive down cost. The City of Los Angeles is paying less than $500 per installed LED luminaire.

But are the municipalities and lighting designers chasing achievable and realistic goals in terms of light levels? Just after SALC, the Lighting Research Center issued a report basically concluding that SSL products couldn't meet the light output required for collector roads in the IESNA standard RP-8-00 (www.ledsmagazine.com/news/7/10/7). Several luminaire makers have questioned that data and we don't know how that will shake out. But are the standards even appropriate for SSL?

At SALC, the City of San Jose presented data from an actual trial indicating that LEDs could be operated at 50% lower light levels relative to legacy lights while also allowing drivers to detect objects from greater distances. The City of Los Angeles has subjective data that suggest LEDs offer far superior visibility.

I know that there are safety issues and large organizations involved. But I believe the outdoor-lighting industry needs to quickly consider new SSL-centric standards as opposed to applying and amending legacy standards to the new technology. For example, the current standards really don't even address the possibility of adaptive controls, or that the classification of a roadway and the light prescribed should be different at rush hour and 9 pm.

Tariffs are a huge problem as well. Apparently most utilities aren't equipped to offer lower rates for LED luminaires in general: offering even lower rates for dimmed lights is a tougher problem. But these rate structures are critical for SSL success past the grant-funded era.

The industry needs quick action in terms of standards and practices that ensure we safely move to the dimmest and most energy-efficient SSL installations possible. And municipalities must be able to get rates that make such investments pay off. Otherwise up-front cost will lead municipalities to make less-efficient choices resulting in more energy waste and higher carbon emissions.

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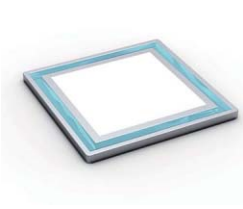
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PRESENTER: Kenneth Morgan Jr., Intertek

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Web Exclusive Articles

LED component assembly benefits from SMT processes

Automated SMT assembly of LED components, enabled by high-quality equipment such as nozzles and feeders, is able to effectively increase throughput and minimize defects.

www.ledsmagazine.com/features/7/9

Interferometry helps optimize high-brightness LED production

Optical profiling provides 3D surface metrology for patterned sapphire substrates used in HB-LEDs.

http://bit.ly/atf0te

FEATURED *events*

IESNA Annual Conference
November 7-9, 2010
Toronto, ON, Canada

Electronica 2010
November 9-12, 2010
Munich, Germany

LED Forum Moscow 2010
November 10-11, 2010
Moscow, Russia

ForumLED Europe
December 7-8, 2010
Lyon, France

LED Expo 10 (India)
December 17-19, 2010
New Delhi, India

The Arc Show 2011
January 12-13, 2011
London, United Kingdom

LED/OLED Lighting Technology Expo
January 19-21, 2011
Tokyo, Japan

SPIE Photonics West
January 22-27, 2011
San Francisco, CA, United States

Strategies in Light 2011
February 23-25,
Santa Clara, CA, United States

Strategies in Light China
May 10-12, 2011
Kowloon, Hong Kong

Strategies in Light Europe
October 3-5, 2011
Milan, Italy

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news views

APPOINTMENTS

Osram Opto Semiconductors appoints new chief executive

Osram Opto Semiconductors, the Germany-based LED manufacturer, has appointed Aldo Kamper as its new CEO. Kamper succeeded Rüdiger Müller on October 1, 2010. Müller, who has now reached retirement age, was appointed head of Siemens' optoelectronic semiconductor business in 1988 after more than a decade with the company. In 1999, he was the founding CEO of Osram Opto Semiconductors, in which Siemens' LED and infrared business was pooled with Osram's lighting competence. Under his leadership, Osram Opto has seen strong growth and the continuous expansion of production capacities in Regensburg, Germany and Penang, Malaysia, as well as technological advances such as thin-film LED technology, surface-mountable LEDs, blue and green laser diodes, and OLED lighting products.

Kamper joined Osram in 1994 and has held various executive positions at Osram Opto in the fields of automotive and visible LEDs. Since 2006, he has held the post of Executive Vice President & General Manager Specialty Lighting at Osram Sylvania in the USA. ◄

MORE: www.ledsmagazine.com/news/7/9/7

RETAIL LIGHTING

Best Buy installs LED replacement lamps from CRS

Best Buy Co, Inc., a multinational retailer of technology and entertainment products, has made a commitment to replace 35,000 50-watt halogen lamps with 6-watt LED-based MR16 lamps from LED lighting manufacturer CRS Electronics Inc.

The initial rollout of 3,150 replacement lamps will be delivered to 50 Best Buy locations. They will be used to highlight digital camera displays and Magnolia Home Theater system rooms, where the capability of dimming lights is essential to provide customers with optimal real-life settings. The replacement lamps are expected to generate an 80% reduction in electrical demand and consumption for Best Buy.

"Our new driver technology allows our lamps to maintain superior performance and [to] dim on electronic transformers and industry-standard dimmers," said Scott Riesebosch, president of CRS Electronics. "Electronic transformer-powered light fixtures represent a significant portion of the market, which, until now have not been able to utilize LEDs without flickering," he added. ◄

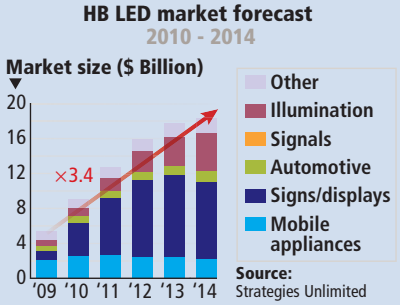
MORE: www.ledsmagazine.com/news/7/9/22

MARKETS

LED market to reach $9.1 billion in 2010

The latest LED market numbers from Strategies Unlimited show that total sales of packaged LEDs are expected to grow by an amazing 68% in 2010, reaching $9.1 billion. The new forecast was revealed by Strategies Unlimited's Vrinda Bhandarkar at the Strategies in Light Europe meeting in Frankfurt, Germany, which had a registered attendance of more than 600 visitors from 44 countries. See our report on page 23.

Despite fears of an industry slowdown in some quarters, Strategies Unlimited has raised its forecast for 2010, having predicted in February that the LED market would grow 52% in 2010. Looking forward, Bhandarkar said that the industry would experience a CAGR of 27.8% from 2009 to 2014, to reach $18.4 billion.



LED backlights for LCD TVs and monitors will be the biggest growth driver, said Bhandarkar. The slowing LCD TV market may reduce projected shipments of LED TV backlights, but the penetration of LEDs will continue to increase.

Meanwhile, the penetration of LEDs into the lighting market has achieved substantial momentum. "We expect this momentum to pick up speed in 2010, with a growth rate of 34% compared to 31% in 2009," said Bhandarkar. Outdoor lighting and replacement lamps will be the fastest-growing segments. The longer-term outlook continues to be highly positive, with a 5-year CAGR forecast of 48% for the lighting sector. ◄

MORE: www.ledsmagazine.com/news/7/10/3

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OUTDOOR LIGHTING

San Francisco and London put out RFPs, DOE Consortium expands

In a busy period for outdoor lighting, which included the Street and Area Lighting conference (see page 37), San Francisco circulated a Request for Proposals for "LED Luminaires with Wireless Monitoring and Control System." The city plans to replace 18,500 cobra-head-type, high-pressure sodium (HPS) street-light luminaires with dimmable LED lights, and also wants to have an integrated wireless communication monitoring and control system (www.ledsmagazine.com/news/7/10/13). The City's purpose is to reduce energy costs, to reduce labor costs for maintenance and operation, and to more efficiently and effectively maintain street-lights via the wireless system.

Meanwhile, in the UK, The Climate Group's global LightSavers LED lighting program sought proposals for a trial of LED luminaires along roads in London (www.ledsmagazine.com/news/7/10/5). LightSavers is looking to undertake LED streetlight trials in London on major arterial roads that facilitate the flow of mixed commercial and private traffic into and through the city, and typically require mounting heights for lighting of 10m or 12m. This is the third trial following two similar trials which are currently being mobilised and for which suppliers have already been selected.

In the US, the Department of Energy's (DOE) Municipal Solid-State Street Lighting Consortium has welcomed as new members the US and Canadian cities that were part of Cree's LED City program. The Consortium will now provide an organizational structure and guidance to these cities (www.ledsmagazine.com/news/7/9/30). A Cree spokesperson for LED City said that the program's efforts will continue in Europe and Asia, as these markets do not yet have the same type of institutional support that is being provided by the DOE Consortium.

In less positive news for LED lighting, a new report released by the Lighting Research Center (LRC) looked at lighting on collector roads, and questioned the economic viability of LED and induction street lights compared to legacy HPS lights (www.ledsmagazine.com/news/7/10/7). The report said that twice as many LED luminaires would be needed to meet the RP-8 criteria. However, our article quotes BetaLED, an LED luminaire maker, as saying that the choice of luminaire was not optimized for the specific application referenced in the report.

The National Electrical Manufacturers Association (NEMA) has published a white paper, LSD 11-2010, entitled "White Paper on Outdoor Lighting Issues and Quality Lighting Applications," which includes updated information on existing regulations, major issues in the industry, and outdoor lighting technologies (www.ledsmagazine.com/news/7/9/16). It identifies specific lighting issues, defines correct lighting terminology, and provides technical guidance applicable to outdoor lighting installations in the US. The publication is intended to be used by anyone dealing with the selection, installation, or management of outdoor lighting systems. ◄

RESTAURANT LIGHTING

Chili's restaurant chain installs 125,000 LED lamps

Brinker International, parent company of Chili's Restaurants and Maggiano's Restaurants, has recently installed LED lighting from Eco-story LED Lighting Solutions (Portland, Maine) as part of a re-lamp project in all of its corporate restaurants. The project involves installing 125,000 LED lamps in the interior and exterior of all 827 corporate restaurants. Eco-story claims this will be "the largest US roll-out of LED lamp technology to date." The project is currently about 80% complete.

After testing the technology in ten stores, Brinker determined its annual savings would be approximately $87.00 per store, per week. Over 827 stores, this equates to more than $3.7 million per year. In addition to saving money, the LED lamps are also improving the look and ambiance of the Chili's restaurants versus traditional lighting, according to Kevin Falconer, Brinker's Senior Director of Design. "Our team studied LED lights for a long time and tested many makes and models, and we feel our stores look better now than before," he said.

The lamps emit a warm-white light with a color temperature of 2700K, and are built using Cree XLamp LEDs. A variety of lamp types have been retrofitted, e.g. 4.9 W LED MR16s have replaced older lamps ranging from 30 to 50W, and 60W PAR20 and PAR30 lamps have been replaced by 6W LED products. Candle bulbs and indoor and outdoor globe lights have also been replaced. ◄

MORE: www.ledsmagazine.com/news/7/10/6

BUSINESS

Toyoda Gosei and Epistar form joint venture

Following an LED patent cross-licensing agreement between LED manufacturers Toyoda Gosei Co., Ltd. and Epistar Corporation (www.ledsmagazine.com/news/7/9/14), the two companies are

forming a joint venture named TE Opto Corporation. The other participant is Twin Hill Co., Ltd., a sales agent for Toyoda Gosei. TE Opto will develop, manufacture, and market LEDs, and will be based in the Neihu District of Taipei, Taiwan. The company is

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due to be established on November 1, 2010 with a capitalization of 23 million Taiwan dollars (equivalent to about USD 730,000).

Toyoda Gosei will own 51% of TE Opto, Epistar will have a 40% share and Twin Hill will own the remaining 9%. The companies say that the joint venture agreement "combines Toyoda Gosei's leading-edge LED technology with Epistar's low-cost manufacturing capabilities to expand the partners' LED sales in the growing market of illumination applications." Since 2006, Toyoda Gosei has worked with Epistar and outsourced the production of some of its LED products to Epistar. ◄

MORE: www.ledsmagazine.com/news/7/9/26

COMMERCIAL LIGHTING

LED lighting at forefront of Osram Sylvania survey

Osram Sylvania has carried out a Commercial Lighting Survey, revealing the priorities and experiences of over 350 lighting designers and facility decision-makers across the education, healthcare, hospitality, office and retail sectors.

The survey shed light on the current and emerging needs of building professionals and defines how highly-efficient LEDs and solid-state lighting (SSL) are shaping the future of commercial spaces.

Among the key findings of the survey, an overwhelming 84 percent of respondents revealed that energy efficiency, operating costs and maintenance are top considerations when making lighting decisions. Lighting has become a top priority for businesses, with most respondents believing that total cost of ownership is important, rather than focusing just on the initial cost.

Another result was that 73% of building and lighting professionals are currently using LEDs or planning to use LED lighting in their commercial spaces. Low maintenance, reduced costs and energy efficiency are the most important advantages of LEDs, but the size of the initial investment is the top barrier to LED adoption. ◄

MORE: www.ledsmagazine.com/news/7/9/19

SOFTWARE

Synopsys acquires Optical Research Associates

Synopsys, Inc., a developer of software and IP for semiconductor design, verification and manufacturing, has acquired Optical Research Associates (ORA), a privately-held provider of optical design software and optical engineering services. The terms of the deal were not disclosed.

The addition of ORA's expertise, technology and products will allow Synopsys to move into the rapidly growing markets associated with displays and solid-state lighting using LEDs, as well as expand into markets such as semiconductor lithography equipment and cameras. With its CODE V and

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LightTools software products, ORA is one of the world's leading developers of optical design and analysis software. ◄

MORE: www.ledsmagazine.com/news/7/10/10

DRIVERS

Carmanah acquires LED driver company Lightech

Carmanah Technologies Corporation, a manufacturer of solar LED lighting and power systems, has acquired Israel-based Lightech Electronic Industries Ltd, for an amount that could reach US$20 million. Lightech manufactures power supplies for LED lighting, supplying major lighting OEMs and distributors. It operates R&D facilities in Israel and California, and manufactures drivers and transformers through EMS contractors in China.

Carmanah, which is based in Victoria, British Columbia, Canada, said that its strategic rationale for the acquisition is to gain access to the large global transition to LED technology by acquiring a company that supplies core components to lighting providers. The deal will also expand the company's offerings, strengthen Carmanah's global presence, manufacturing, delivery and routes to market, and generate operating and R&D efficiencies. ◄

MORE: www.ledsmagazine.com/news/7/10/1

LIGHTING RESEARCH

Seoul LEDs light ZEBRAlliance house

The ZEBRAlliance (Zero Energy Building Research Alliance), a public/private research partnership, has built four energy-efficient homes in Oak Ridge, TN, one of which is lit by LED-based solid-state-lighting (SSL) products based on Acriche LEDs from Seoul Semiconductor.

ZEBRAlliance built the homes for a 30-month test of the energy-saving technologies. In the case of lighting, the Alliance will monitor energy usage, maintenance requirements, and lighting quality. At the end of the tests, results from the SSL home will be compared against similar data gathered from a house that uses compact fluorescent lighting. A spokesperson said that the project will help raise awareness about LEDs and their ability to provide energy-saving, cost-efficient, and longer-lasting lighting solutions than homeowners currently use. ◄

MORE: www.ledsmagazine.com/news/7/9/27

LED MANUFACTURING

Cree builds 150-mm LED wafer line

LED maker Cree, Inc. has announced a new 150-mm LED wafer production facility in Research Triangle Park (RTP), North Carolina, and anticipates hiring nearly 250 more employees by 2013 to staff the expansion. The new LED wafer production line will be located in Cree's existing RTP production facility, and will allow Cree to produce 150-mm LED wafers that are more than double the size of current ones. By increasing the number of LEDs from a single wafer, this move will help to make LED lighting more cost-effective, says Cree. The new LED wafer production line is scheduled to be installed over the next several quarters with a target of having the first products qualified on this line by June 2011.

According to a Local Tech Wire article, Cree will invest $135 million in the new line. The same article said that Cree is considering locations for a $392 million plant to manufacture LEDs in Durham County, NC, but is also considering sites in China and Malaysia for the facility. ◄

MORE: www.ledsmagazine.com/news/7/9/20

LIGHTING

LED lighting features strongly in Philips' strategic vision

Philips has unveiled its Vision 2015 strategic plan, in which solid-state lighting plays a major part. Rudy Provoost, CEO of Philips Lighting, said that the global lighting market is expected to grow at a CAGR of around 7-9% from 2010 to 2015, to around EUR 80 billion (around $105 billion), with LED lighting accounting for just over half the total. He described LED adoption as "the key driving force for growth in the lighting industry."

Philips estimates that the market for lighting applications and solutions in 2015 will be around twice the size of that for components and light sources, and that LEDs will account for a large chunk of each of these segments. Provoost said that digital lighting is driving significant opportunities for both light sources and applications. "LED-based applications offer increased possibilities for customers," he said. Examples include intelligent solutions such as controls and system integration, dynamic and interactive lighting applications, and "breakthroughs in total cost of ownership."

For lighting in general, there are large opportunities in emerging markets, driven by population growth, urbanization and increasing per-capita income. This growth will occur alongside steady growth in mature markets, driven by legislation concerning inefficient products, and a move towards higher-value, energy-efficient products. ◄

MORE: www.ledsmagazine.com/news/7/9/17

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OLEDS

Pilot OLED manufacturing lines planned in USA and Germany

The US Department of Energy has announced that the first pilot manufacturing facility for OLED lighting panels in North America will be based in Canandaigua, New York (www.ledsmagazine.com/news/7/10/20). Meanwhile, Osram Opto Semiconductors plans to invest around EUR 50 million over the next three years to build an OLED pilot-production facility in Regensburg, Germany (www.ledsmagazine.com/press/26996). Commissioning of the production line is scheduled for mid 2011.

In January 2010, the DOE awarded $4 million in American Recovery and Reinvestment Act funds to Universal Display Corporation (UDC) and Moser Baer Technologies, Inc. (MBT). DOE, UDC, MBT and New York's Smart System Technology & Commercialization Center (STC) in Canandaigua are partners on the project, which leverages an $11.5 million investment from MBT, state government incentives available through the STC, and municipal tax credits. The pilot facility will be designed, built and operated by Moser Baer, and should be able to produce more than 1,000 panels per day. ◄

LIGHT SOURCES

Bridgelux introduces five-year warranty on LED products

Bridgelux, Inc., an LED chip and array manufacturer based in Livermore, CA, has introduced a five-year warranty on all of the company's integrated LED arrays and modules. Although some luminaire makers now offer a five-year warranty on LED-based luminaires, Bridgelux is thought to be the first manufacturer to offer this warranty at the LED component level.

The move has been driven by the need for OEMs and luminaire manufacturers to offer longer warranties for their LED-based SSL products. This helps meet the demands of programs such as Energy Star and provides assurances to the marketplace about the viability of SSL. OEMs typically need to offer a minimum of three years' warranty, and often five years. In the case of outdoor lighting, this can be extended to 7-10 years.

The warranty will cover manufacturing defects and will ensure that the product performs as advertised. Jason Posselt, VP of marketing for Bridgelux explained that the warranty provides customers with the assurance that the LED product will work, so they can move ahead quickly with new lamp or luminaire designs. The warranty helps to mitigate the business risk for the end customer as it brings its products to market. It also helps with cost-of-ownership issues, says Posselt, since the warranty means any defective parts can be replaced without cost. ◄

MORE: www.ledsmagazine.com/news/7/10/15

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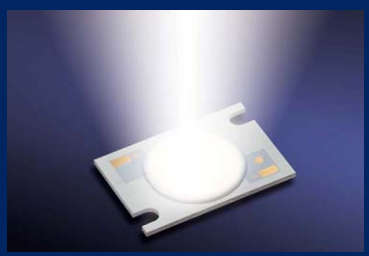

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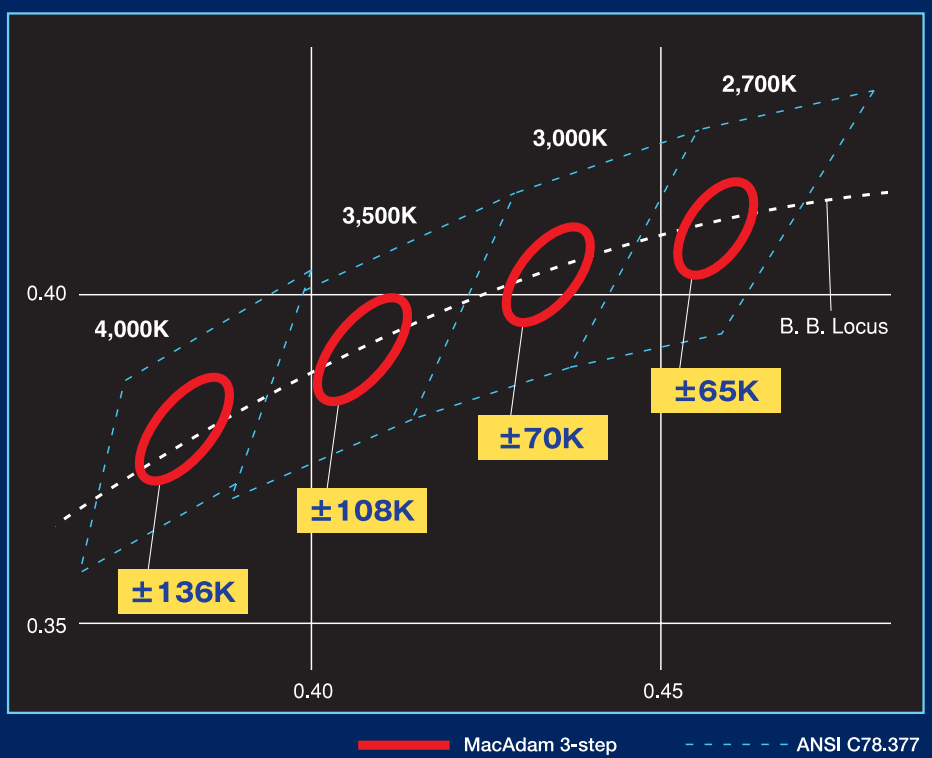

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funding + programs

AC-DC rocks the boat for LM-79

An apparent loophole has come to light in the way the performance of certain LED lighting products is measured according to the LM-79-08 testing protocol "Electrical and Photometric Measurements of Solid-State Lighting Products." This also has repercussions for programs such as Lighting Facts, Energy Star and others, which rely on LM-79 measurements.

The loophole concerns LED lamps that are able to operate directly from either an AC or a DC supply, particularly MR16 lamps. However, there can be a considerable difference in performance depending on whether an AC or a DC supply is used.

LM-79 testing allows the use of either AC or DC supply. The standard says that "the SSL product under test shall be operated at the rated voltage (AC or DC) according to the specification of the SSL product for its normal use."

The loophole came to light when LEDs Magazine was sent test data for an MR16 lamp, bought in a major retail store in the US, that carries a Lighting Facts label. The label states that the light output is 295 lm, the power is 6W, and the efficacy is 49 lm/W.

When the MR16 was tested at 12V DC, the performance was reasonably close to the stated figures on the Lighting Facts label, with light output of 266 lm at 6W, and 44 lm/W efficacy. However, when tested on a 12V AC supply, the output was only 185 lm, the power was 4W and the efficacy was 45 lm/W.

In other words, the light output measured at 12V AC was only 70% of the value when the lamp was operated at 12V DC.

Crucially, in North America, the vast majority of MR16 lamps in "real world" situations are connected to a 12V AC supply powered by either an electronic or magnetic transformer. This means it is highly questionable whether presenting DC data for an MR16 can fit with the "normal use" requirement in LM-79.

After our initial story was published (www.ledsmagazine.com/news/7/10/8), the Lighting Facts program said it would require all labels to state whether testing was performed under AC or DC conditions. ◄

MORE: for further updates to this story, see www.ledsmagazine.com/Regional.

The Scope LED Monorail/Track Light from Edge Lighting (bottom), and the Design Pro LED Modular and Disc System from Kichler Lighting (top) were among the winners in the SSL fixtures category of the Lighting for Tomorrow 2010 competition. The Philips EnduraLED A-Lamp won the replacement lamp category, and Leviton, Lutron and Legrand/Pass & Seymour were all winners in the lighting control section.

MORE: www.ledsmagazine.com/news/7/9/29.

Global Lighting Forum launches LED Working Group

Representative groups from the world's lighting industry have announced an initiative to co-ordinate and promote solid-state lighting (SSL) technology at a global level. The 4th Meeting of the Global Lighting Forum (GLF), held in Shenzhen, China, included the inaugural meeting of the GLF's LED Working Group.

The GLF is a forum of lighting organizations from Australia, Brazil, China, Europe, India, Japan, Taiwan and the USA. It represents over 5,000 lighting manufacturers and $50 billion annual sales.

The GLF says that LEDs hold great promise to revolutionize lighting because of their inherent benefits of energy efficiency, light quality, longevity and adaptability. The GLF's Chairman, Jan Denneman, said that LEDs will play a dominant role in nearly every lighting application. "The world will witness a revolution in lighting that will help reduce energy consumption while enabling new lighting experiences to be developed," he said.

Immediate priorities for the GLF include liaising with stakeholders, including governments and international organizations, to ensure that the quality of LED products provide consumers with a good experience - this will include proposing performance requirements attuned to the needs of different markets.

The group will also assist with international standards development and encourage the harmonization of standards in different regions of the world. Another role will be to produce educational material on SSL, including the development of best practice guides and a guide to SSL nomenclature. ◄

MORE: www.ledsmagazine.com/news/7/9/6

funding + programs

EPA releases Energy Star Luminaires specification second draft

The US Environmental Protection Agency (EPA) released draft 2 of the Energy Star Luminaires version 1.0 specification at the beginning of October 2010. The draft 2 specification and the accompanying cover letter can both be viewed on the Energy Star Luminaires website (www.energystar.gov/luminaires). EPA anticipates finalizing the Luminaires v1.0 specification in November 2010, and is proposing an effective date of September 1, 2011. The Agency will publish a final draft prior to finalizing the specification.

Draft 1 of the Energy Star Luminaires v1.0 specification was released by EPA on May 10, 2010. It's important to note that the Residential Light Fixtures (RLF v4.2) and Solid State Lighting (SSL v1.1) specifications remain in effect until the Luminaires specification is finalized and becomes effective.

Among the changes from draft 1 to draft 2, the efficacy requirement for non-directional luminaires was revised to 65 lm/W, with a planned increase to 70 lm/W scheduled to take effect two years later. The change was made to include what is expected to be broadly accessible and cost effective as of the specification's effective date in 2011.

Also, correlated color temperature (CCT) values have been expanded to allow 5000K for commercial luminaire types only. EPA is concerned that with the increased efficacy requirements, allowing CCTs above the 4100K residential limit may lead manufacturers to shift residential products towards high CCTs which more easily achieve compliance with efficacy requirements, but are generally less preferred by consumers. ◄

MORE: www.ledsmagazine.com/news/7/10/4

EU project to accelerate uptake of quality, affordable LED lamps

A group of 22 European companies and academic institutions are working together in a three-year project entitled "Consumerizing Solid-State Lighting (CSSL - www.ConsumerizingSSL.eu), which is partly funded by the European Union and EU countries.

The CSSL project aims to develop technology and application breakthroughs as well as new market approaches in order to speed up the availability of affordable high-quality LED lamps to replace the ordinary light bulb in the home. In this way, the project plans to help keep Europe at the forefront of LED lamp development and market introduction.

The CSSL project describes itself as being all about building a European "consumer LED ecosystem" encompassing the entire value chain from LED die and light sources through to consumer luminaires and lighting controls. Some of the partners are utility companies.

One specific project focus is gallium nitride (GaN) on silicon wafer processing, which could potentially lead to reduced LED costs. Another focus is mains-compatible LEDs and electronics, in order to reduce the number of lamp parts, and a third is dimmer-compatible LED lamps and electronics. The team is also exploring other ways to accelerate the uptake of LED lamps. With the support of utility companies the ecosystem will gain-end user insights and explore new business models that would further fuel growth. ◄

MORE: www.ledsmagazine.com/news/7/10/18

FTC sues Lights of America over deceptive claims for LED lamps

The US-based Federal Trade Commission has filed a complaint against Lights of America, Inc. (LOA), a California-based light-bulb manufacturer, and its principals, to stop them from misleading consumers by exaggerating the light output and life expectancy of its LED bulbs. As part of the FTC's continuing work to stop deceptive advertising, the agency filed a complaint charging that since 2008, LOA has overstated the light output and life expectancy of its LED bulbs on packages and in brochures. The agency also charges that LOA misled consumers about how the brightness of its LED bulbs compares to traditional incandescent lights. ◄

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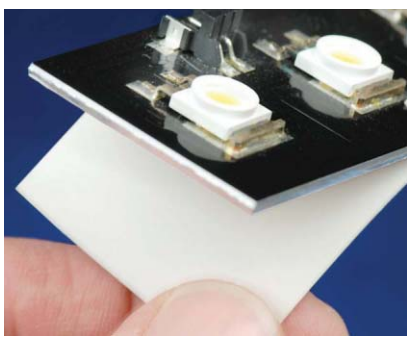

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conferences | SIL EUROPE

Strategies in Light Europe addresses market adoption of LED lighting

Part 1 of our report from the 2010 Strategies in Light Europe conference describes the activities of the European lighting industry, the rise of LED modules, and how LED lighting is shaping the future of light. **TIM WHITAKER** reports.

With the theme of Accelerating the Market Adoption of LED Lighting, the inaugural Strategies in Light Europe conference took place in late September in Frankfurt, Germany. A total of 23 presentations were accompanied by two workshops, one on Standards and the other entitled "Building the Perfect Luminaire." As described on p. 9, Strategies Unlimited's Vrinda Bhandarkar presented an LED market overview and forecast. Another highlight was McKinsey's presentation entitled "Country Road or Expressway: LED at the Crossroads" – see the article on p. 31. Presentations not covered in this article will be discussed in one or more follow-up articles to be published on our website.

SIL Europe 2011 takes place in Milan, Italy on October 3-5, 2011.

Shaping the future of light

Martin Goetzeler, CEO of Osram GmbH opened the main conference by discussing the decision makers who are shaping the future of light and are asking questions on two main subjects. "These are how can we save energy, and how can we optimize the quality of life," he said. "LED lighting contributes to both in a significant way."

Saving energy is clearly very important for decision makers. "Many companies have CO_2 on their agenda as a business target," said Goetzeler. "They can save up to 60% of the energy used in lighting by converting to LEDs." However, cost efficiency is also very important, and the total cost of ownership must be considered, which includes acquisition, maintenance and replacement, as well as the energy costs. Goetzeler said that LED efficiency has increased from 30 lm/W to 150 lmW within 7 years. "Osram invests close to 50% of its R&D budget into LEDs at present," he said, "but the company is also trying to drive the entire value chain."

A major challenge is the need for information and education among consumers. In a survey, more than 50% of participants underestimated the energy-saving potential of CFLi lamps, while one-third had no opinion about LED lamps, since they had no knowledge of the products. For this reason, said Goetzeler, Osram is launching a consulting campaign in DIY and retail stories in 10 European countries, lasting for more than half a year. This will explain to customers the difference between incandescent and energy-saving lamps, including LEDs.

FIG. 1. Martin Goetzeler, CEO of Osram GmbH, opened SIL Europe 2010 and spoke briefly about OLED technology, which he said "creates even more opportunities in lighting going forward, and is complementary to LED technology." He estimated that OLED is 4-5 years behind LED in terms of mass production. Osram Opto showed its new PirOLED luminaire at the show, and also announced that it is building a pilot production line in Regensburg, Germany (www.ledsmagazine.com/press/26996).

On the professional side, Osram conducts energy audits to demonstrate the possibilities. For example, in the state theatre in Kassel, an audit revealed the potential for 70% energy reduction through the installation of LED downlights. As shown in Fig. 2, the maintenance and energy-cost savings with LEDs offset the initial investment. And, under a performance leasing contract, customers have a positive cash flow from the outset, because the energy saving is higher than the amortization and financing costs. In the Q&A session, a questioner said that the energy lobby in France is trying to convince people there is not much point saving energy with lighting because this just increases the heat to be produced by the heating system. Goetzeler responded that "you only have the answer if you look at the whole building," which includes heating, air conditioning etc. In fact, Osram is able to offer energy audits for the entire building in partnership with Siemens' Building Technologies group.

The second question, relating to quality of life, has four main aspects, said Goetzeler:

security, comfort, design and entertainment. Using the example of a car, he said that LEDs provide the technology behind advanced and adaptive forward lighting, but also enable pre-crash and pedestrian sensors, night-vision systems, color-on-demand for interior lighting, and drowsy driver detectors, which all contribute to the different quality-of-life aspects.

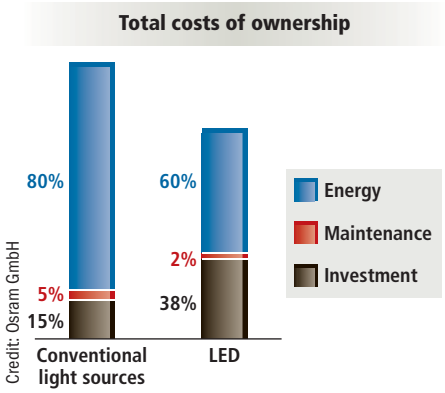

FIG. 2. Savings in energy and maintenance costs outweigh the higher initial investment required for LED lighting compared with conventional light sources.

The need to provide comfort at work raises the question of how to cover the circadian cycle in daily life. "We have to try to copy what the sun is doing, and shift from 8000K to 3000K," said Goetzeler. Outside, modern street lighting makes "streets more secure, and makes cities remarkable," he said. Energy efficiency is one aspect, but beautification is another, and adds to the character of the city. "Architainment" and façade lighting can have the same effect. "LEDs allow light to become a building material," said Goetzeler.

The market opportunities addressed by Osram are expected to grow at a CAGR of 10-11% from 2010 to 2015, at which time the share of SSL and traditional technologies will be 65:35 (compared with 40:60 in 2010). This includes all applications where Osram is active, and does not include luminaires. In the Q&A session, Goetzeler was asked whether bulbs and tubes are going to disappear. "It's not impossible, but will take more than 10 years," he answered. "It will be necessary to exchange the entire installed lighting inventory." He also explained that Osram is still working in other lighting technologies, and still sees significant potential in HID lamps, for example, since LED will not take over immediately.

With regard to pricing, Goetzeler said that double-digit reduction in pricing of LEDs will continue for a couple of years. "On the other side, if you come down too quickly, you might risk that the innovation stops," he said. "You have always to balance between what is the right price and how do we still get innovation, because we still have some work to do in order to optimize the LED itself and the solution." When asked about competition from Chinese manufacturers, he said that everything should be on a level playing field. "Companies that carry IP should be treated fairly," he said.

Europe's lighting industry

Jan Denneman, president of the European Lamp Companies Federation (ELC), described the efforts of the European lighting industry (as represented by ELC for lamps, and CELMA for luminaires and components) to promote quality LED lighting solutions (for more on CELMA and ELC, see www.ledsmagazine.com/features/7/8/9).

"LED lighting is much more than energy saving only," said Denneman. "It offers new opportunities in enhancing the lighting experience, and allows solutions that are closer to the needs of humans for natural light." He called for "human-centric" lighting design in which there is a balance between visual, emotional and biological requirements and experiences.

The objective of the European lighting industry is to increase market opportunities for quality LED lighting products and systems by speeding up and increasing the adoption of LED products and luminaires. This is done by market education, and through work to develop standards and future legislation. The industry is in a "shaping mode" with respect to standards and regulation, said Denneman (see Fig. 3), and is actively involved in the drafting of EU legislation that determines the regulation landscape for LED lighting products. This includes the existing and forthcoming EcoDesign Regulations, and the activities within the Digital Agenda for Europe (see below).

Market surveillance is crucial, stated Denneman, claiming that currently there is a large share (35%) of non-compliant products on the European market. "This is causing customer dissatisfaction, creating a non-level playing field, and hampering the penetration speed of LED lighting," said Denneman, adding that the issue will get worse as regula-

China's SSL industry

China is establishing itself as a global powerhouse for the LED industry. Wu Ling, general secretary of the China Solid State Lighting Alliance, said that SSL is one of the "golden opportunities for developing green and sustainable industries." She said that if the average LED fixture efficiency reaches 150 lm/W and LED lighting takes 50% of the market, then the annual savings for China will be 340 billion kWh. In comparison, the $24 billion Three Gorges Project has an output of 85 billion kWh/year.

China already has a complete SSL industrial supply chain, with more than 4000 enterprises, and 2009 sales of $11.8 billion. Lighting is a key application: architectural and functional lighting enjoy market shares of 23% and 13%, respectively, compared with 21% for backlighting and 20% for displays. Both the 2008 Olympic Games and the 2010 Shanghai World Expo – which used around 1.05 billion LED chips in various installations – were important showcases for LED lighting.

Wu Ling explained that China has a Municipal Showcase Project involving 21 cities, which between them have already installed over 1.7 million LED fixtures (including 200k roadway lights, and 720k in architectural applications). China also has 4 LED industrial areas and 7 national LED industrial parks.

China's National Development and Reform Commission has set industrial targets for 2015 of sales in excess of RMB 500 billion ($75 billion), annual electricity savings of 100 billion kWh, and the creation of 1 million jobs. By this stage, China would aim to have 2-3 large-scale LED chip companies and 3-5 leading SSL application companies, said Wu Ling. The next issue of LEDs Magazine will feature a major article on China's SSL industry. ◄

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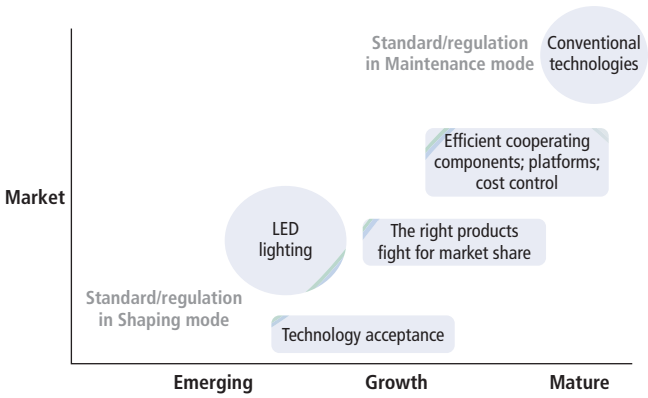
tions become more demanding. In the absence of other options, the European lighting industry is "investigating the feasibility of industry-driven market surveillance," he said.

In conclusion, Denneman said that the European lighting industry is seeking support from the EU and Member States for strong and rapid EU legislation to ensure that only good-quality LED products can reach EU consumers. As well as market surveillance, the industry also wants to see harmonized initiatives (including financial), and increased global cooperation and exchange of information, which will remove the need for national initiatives.



Source: ELC/CELMA/J.Denneman

FIG. 3. In terms of standardization and regulation, the LED lighting business is currently in a shaping mode.

In a Q&A session, Denneman confirmed that the need for a European quality label is being discussed. "Yes there are plans and yes we are considering if this would help improve the quality of LED lighting in Europe. The UK's EST has a label already, and there are activities by ZWEI in Germany. In principal, we think a quality label is a good thing, but it needs to be European wide. Also, quality labels don't help if there is not a good surveillance mechanism in place." This touches on a concern in the EU, he said, compared with the USA where Energy Star is coupled with Caliper, and the US federal government can enforce laws. "But the EC cannot enforce laws, except in the field of competition law," he said.

Denneman was asked whether market forces or government incentives were more important for growth. "Market forces," he replied. "Incentives are important and useful, but a customer should basically want to buy an LED bulb. If that's not the case, the thing won't fly. Governments need to ensure a level playing field, and the EC has helped to remove inefficient products from market." An "unbeatable" product like the incandescent lamp is very cheap and

"people like the light from it, so it will stay in the market forever without the ban," said Denneman. However, the next step is to make sure that the efficient products remaining in the market are used in an efficient way.

Denneman agreed with a comment that Europe is falling behind countries such as Taiwan and China, where investment is much higher than the collective level from Europe. Martin Goetzeler said that the industry "could do more if we had more support from the government side in starting to implement LEDs in pilots and programs." Such "green procurement initiatives" are one of the drivers in countries such as Taiwan and Korea, and in China you get a tax rebate if you buy an LED lamp, he added.

European Commission activities

Unveiled earlier this year, the Digital Agenda for Europe outlines policies and actions to develop a flourishing digital economy by 2020. John Magan, Deputy Head of the Photonics Unit of the European Commission (EC), said that SSL is one of few technologies specifically addressed in the Digital Agenda. The focus is on the electricity-consumption savings that can be achieved by combining SSL with intelligent light-management systems. In late 2011, said Magan, the EC will publish a Green Paper on SSL to explore the barriers to SSL adoption, and to put forward policy suggestions. Input is required from now until early 2011, and Magan called on everyone to contribute to the process. Another activity is that, by 2012, Member States will be required to include specifications for total lifetime costs (rather than initial purchase costs) for all public procurement of lighting installations.

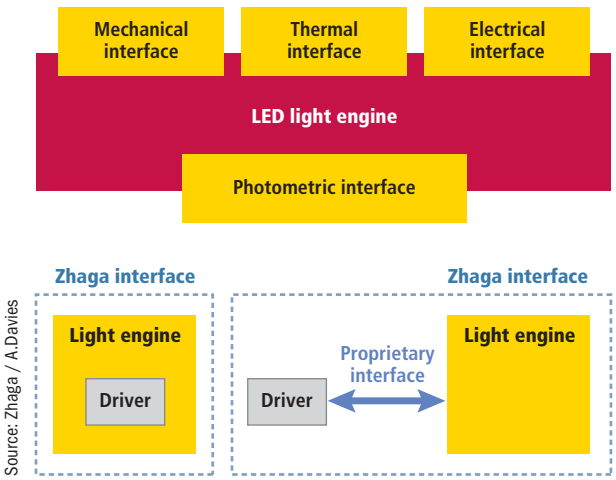
The EC will also support SSL demonstration projects via the Competitiveness and Innovation Programme (CIP). The plan is to have a small number of large-scale projects that will help raise awareness of SSL as well as demonstrating the technological capabilities. The project will receive 50% funding, and should have participants from throughout the value chain. Proposals will be sought in the first half of 2011, and the projects are expected to start towards the end of the year.

The EC also funds research, and there is a current call for proposals related to Organic and Large Area Electronics and Photonics (including OLEDs). I
actions will include
(including OLEDs) ar
ruptive technologies, which will include LEDs. More details are at http://cordis.europa.eu/fp7/ict/photonics/. The EC is also starting to look ahead to its 8th Framework Programme (FP8) for research, starting in 2014, and needs "visionary input in lighting, photonic and organic electronics," said Magan.

Close

EU regulations on lamps and modules

Also representing CELMA and ELC, Peter Besting of Panasonic Electric Works Vossloh Schwabe GmbH spoke about modules



Source: Zhaga / A.Davies

FIG. 4. The Zhaga consortium is developing standards for LED modules/light engines. (top) Yellow areas are within Zhaga's scope, allowing interchangeability between modules from different manufacturers. The red areas are NOT within Zhaga's scope, allowing differentiation (e.g. remote phosphor vs discrete LEDs). For drivers and electronic control gear, features such as the size, fixing points and connector positioning are in the scope of Zhaga, but the internal circuitry is not. This applies whether the driver is integrated into the module, or connected via a proprietary interface (bottom).

and lamps in relation to EU regulations. "Minimum quality requirements for LED lamps & modules are considered a key factor to guarantee consumer satisfaction in LED lighting and to grow the LED market," he said. ELC and CELMA are providing input on quality requirements to the Commission as it prepares part 2 of the EcoDesign Regulations. The current EU Regulation 244/2009 (EcoDesign part 1) is restricted to non-directional lamps. The recommendation is to include LED modules in part 2, and to require efficacy >50 lm/W in 2012, increasing to >60 lm/W by 2015. Part 2 will also include directional lamps, and the industry has already agreed and defined minimum output values for different lamp types, independent of the light-source technology.

Besting explained that consumers want a choice of LED lamps and modules, and setting minimum quality levels will guarantee basic performance and avoid frustration and disappointment. However, the industry will also supply top-quality products for applications where a high price is justified. "International standards allow comparison and evaluation," said Besting. "Regulation should ensure a minimum quality level, but should also leave sufficient space for differentiation in view of different application/usage and competitiveness." *continued on page 57*

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Bulb Type (mini Krypton Type)

*Coming soon

- 3.7W
  ø43 × H73mm
  E12 / E14 / E17 Base

LumiDas-CL

Candle Type

- 5W
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Candle Type (mini Krypton Type)

*Coming soon

- 3.7W
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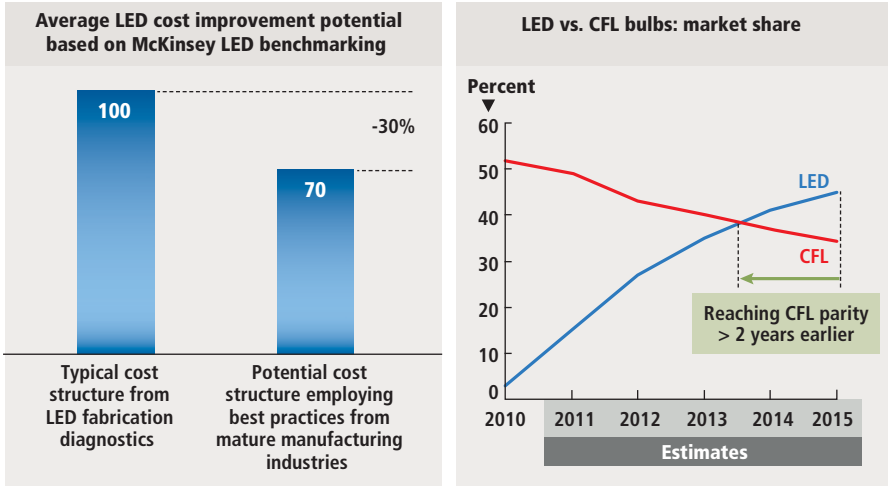
lighting | INDUSTRY STATUS

LED lighting at the crossroads: country road or expressway?

The LED lighting industry faces five major roadblocks, but if these can be overcome then the market will be able to accelerate rapidly, say **FLORIAN WUNDERLICH, DOMINIK WEE** and **OLIVER VOGLER**.

The advantages of the new LED lighting technology are well attested and beyond doubt. Nevertheless, LED lamps have achieved little market penetration so far and are predicted to make far slower market progress than comparable disruptive technologies. McKinsey research conducted by the firm's LED Competence Center has revealed the underlying reasons behind the slow uptake, and this article presents the means to address them and so accelerate LED penetration. If manufacturers, retailers and regulators collaborate to overcome the five major barriers to adoption that the research has identified, LEDs could dominate the lighting marketplace by 2015.



Source: McKinsey LED Benchmarking Initiative; KLA Tencor; McKinsey Conjoint Model on the light bulb market.

FIG. 1. Accelerating LED adoption by applying best manufacturing practices.

Environmentally and economically superior

LED is truly a revolutionary lighting technology. It offers a number of important features, including many that cannot be matched by existing incandescent, compact fluorescent (CFL), or halogen lights. Among LEDs' advantages are greater color variability, instant-on capability, dimming capacity, and freedom in design. The efficiency of LED lamps makes them significantly superior to CFL today in terms of total cost of ownership (TCO), as LED bulbs can generate more than 100 lumens per watt of electricity against 60-75 lm/W for CFLs while lasting three to five times longer. LEDs' fully-loaded costs become lower than those of typical fluorescent lights in roughly 6 years.

LEDs are also superior from an environmental perspective. They contain no mercury, so their disposal is significantly less problematic than CFL or traditional fluorescent tubes. From a carbon-abatement perspective, LED's energy efficiency creates a substantial savings potential. Compared to traditional incandescents, LED lamps can reduce energy consumption by more than 80 percent.

Overcoming the roadblocks

In spite of the advantages of LEDs, even optimistic market forecasts predict that LED retrofit light bulbs will not achieve 50 percent household penetration in the United States for 10 years or more. This pace would be slower by half or more than was achieved by DVDs, broadband internet, and television.

To understand what is holding LEDs back, McKinsey conducted research involving store visits and a survey of key LED industry players. The results highlighted five key roadblocks, for each of which we developed solutions based on both existing McKinsey knowledge and new insights derived from additional proprietary research, including a conjoint analysis of consumer shopping behavior.

1. LED unit costs are too high

Not surprisingly, our survey shows that industry leaders agree that this constitutes the top roadblock for LED right now. At EUR 20-40, LED lamps are still four times the price of an equivalent CFL in the 40-watt-equivalent product range.

Solution: reduce costs by applying manufacturing best practices. By employing best practices drawn from mature manufac-

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turing industries (e.g. increasing yield and automation levels), such as semiconductor foundries, we believe that lowering the cost of LED lamps by as much as 30 percent as a one-time effect would be readily achievable in the short term. The one-time reduction would augment a typical annual cost reduction of around 20 percent, according to most experts (Fig. 1).

Our analysis indicates that if manufacturers pass on the cost reduction to consumers, LEDs could achieve the same market share as CFL (about 40 percent) by 2013, 2 years ahead of the current forecasts.

2. Product positioning at retail is weak

Our store visits showed that LED lamp manufacturers are not making sufficient investment in retail presentation. We encountered signage that muddied the distinction between the energy efficiency of LED and CFL lamps, and 70 percent of the stores we visited had no dedicated section for LED lamps. More than half the stores in our tour had very limited assortments of LED lamps, with only standard white lamps on offer, in only the most standard wattages.

Solution: clear and informative consumer guidance. Our analysis reveals that a handful of improvements in merchandizing techniques could generate significant increases in consumer adoption (Fig. 2).

Applying their trade spend budgets as necessary, manufacturers should encourage retailers to do a number of things: segment lighting technologies for display; feature LED products on special promotional shelves and on the ends of aisles; and deploy showcases enabling comparisons of brightness, color, and temperature from technology to technology. Manufactures should also be sure that consumer information literature is displayed right beside the segmented LED products.

3. Principal-agent conflicts abound

In most commercial lighting situations (e.g. corporate offices or building lobbies), builders make the majority of the lighting decisions based on initial cost, rather than longer-term benefits. On the other side of the ledger, the tenant pays the operating cost, meaning they would likely prefer LED, if only they were in a position to make the decision.

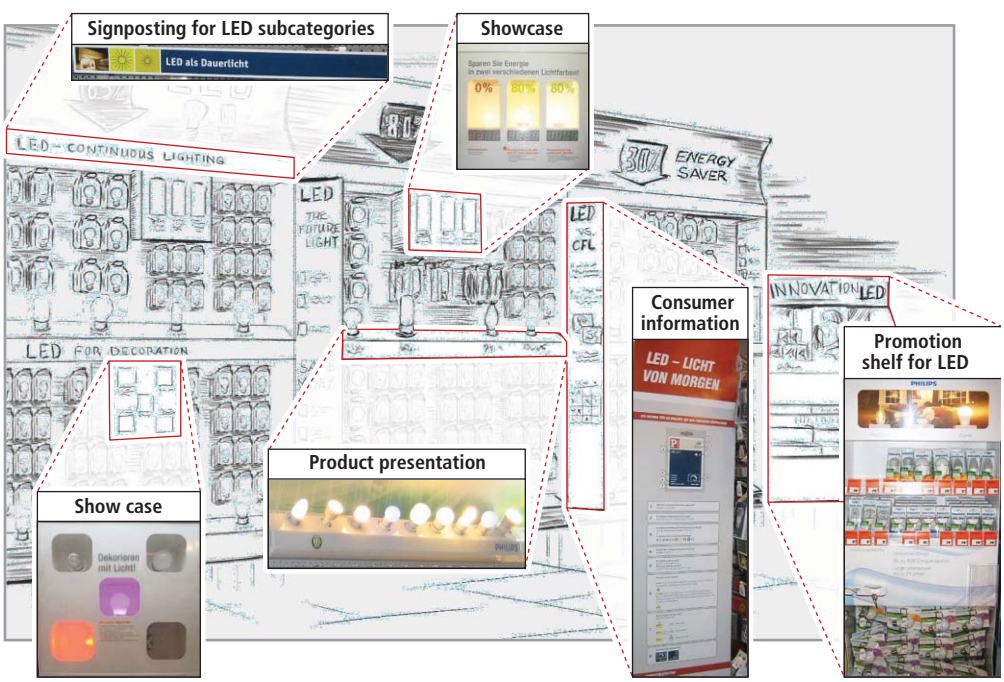
Solution: create third-party lighting service providers. These interests, now conflicting, create an opportunity for the introduction of a new business model to satisfy both sides: lighting service provision by a manufacturer, utility, facility-management company, or a third party. A business of this type would sign contracts to provide not only the up-front investments, perhaps with financial participation from an investor, to enable LED lamp installation, but it would also provide the maintenance and upkeep of the LED fixtures, and charge occupants an hourly rate for light.

By removing the purchasing decision from the builders, such a provider could price its services to begin delivering on the TCO promise of LED to customers from the very first day, while also earning a decent margin for its services.

We calculated, for example, that by supplying and maintaining street lights across an entire city of one million people, an LED provider could generate energy savings on the order of 22 percent. At average rates, this model would save the municipality roughly EUR 2.3 million per year, mainly through electricity savings.

In the same way, corporate customers could also benefit from such an arrangement. Their lighting costs would be reduced due to lower energy consumption, and the corporations themselves would bear none of the up-front investment costs. In addition, the maintenance burden associated with lighting would be reduced and completely outsourced.

> "The industry can overcome these roadblocks, by acting in close partnership with component manufacturers, retailers and regulators."



Source: McKinsey store visits (12 stores, July 2010, Munich).

FIG. 2. Clear and informative consumer guidance is key to market LED products.

4. Direct regulatory support is lacking

Despite the banning of incandescents in more and more countries, LED adoption has little direct government support in the consumer sphere against competing traditional lighting alternatives like CFLs. In contrast, other energy-saving technologies enjoy more support: Germany for example provides EUR 2.4 billion in solar panel subsidies per year (paid by consumers), while the EU is considering strong regulations to reduce the CO_2 output by automobiles and other vehicles lighter than 3.5 tons. Analysis shows that solar subsidies achieve CO_2 abatement at a cost of EUR 630 per ton, and emission reduction in cars achieves this at a cost of roughly EUR 140 per ton.

Solution: publicize LED's remarkable environmental and cost advantages. Our analysis reveals that switching from incandescents to LED can actually realize a profit from CO_2 abatement, of approximately EUR 130 per ton CO_2 abated, due to the energy-saving potential of LEDs (Fig. 3).

LED manufacturers have an irresistible case for their technology, which must be presented to regulators. A basic calculation shows that, by funding LED retrofits at the same level as solar subsidies (EUR 2.4 billion), Germany could abate 50 megatons of CO_2, as a result of the lower prices and higher penetration this would achieve. This is a 10-fold savings over what the solar subsidies are projected to deliver. In Asia such advantages are already being realized, as in Taiwan, where the government has mandated 100 percent LED traffic lights by 2011. In the EU, similar LED programs could contribute significantly to the "20-20-20" EU goal (20 percent CO_2 reduction by 2020).

"LED adoption has little direct government support in the consumer sphere against competing traditional lighting alternatives like CFLs"

5. The uncertainty of technology transitions

Past examples of technological transitions reveal risks as well as benefits for incumbent players. When in under 10 years cameras changed from analog to digital, for example, companies like Leica nearly vanished from the market in Germany, while others like Canon managed to increase market share.

Solution: follow the lead of successful traditional semiconductor players. When managing the transition from traditional lighting to opto-semiconductors, incumbents can incorporate the factors that made traditional semiconductor players successful. These include rigorous management of an R&D roadmap to realize 20 to 30 percent annual cost reduction; a learning engineering organization to bring yield curves up quickly (starting at below 10 percent); fast decision processes to manage product life cycles of under 1 year; and sophisticated planning processes to manage 30+ percent volatility in volumes year-to-year in combination with significant capital commitments.

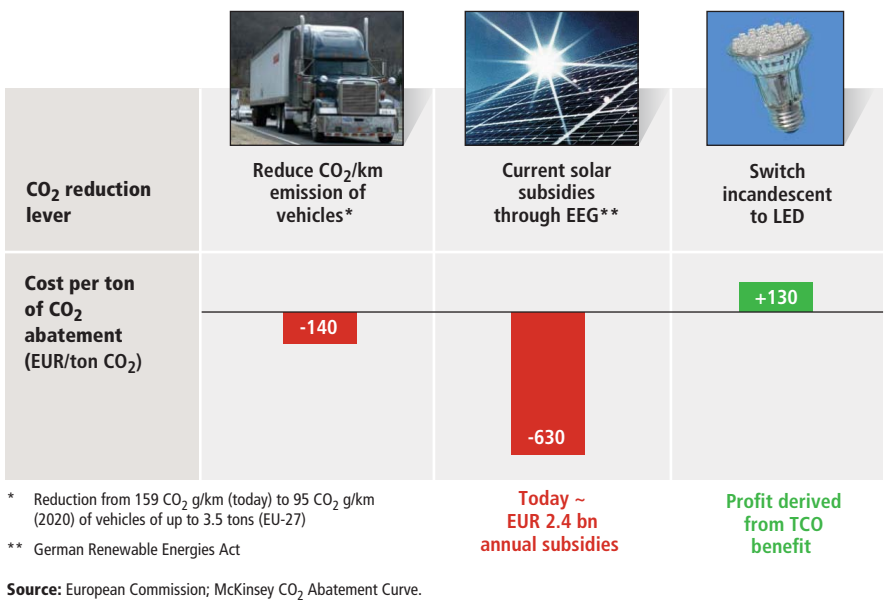


FIG. 3. CO_2 abatement in vehicles and solar comes at a high cost. LED lighting is economically more attractive, but is not yet in focus.

Shifting into high gear

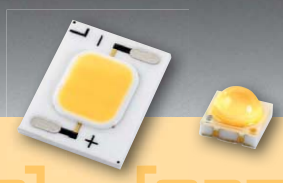
The five roadblocks that we have discussed have kept LED lamps in the slow lane to adoption, with society and consumers largely missing out on their great potential. We have indicated our strong belief that the industry can overcome these roadblocks, by acting in close partnership with component manufacturers, retailers and regulators. A cleared path to accelerated LED adoption will lead also to a sustainably profitable, large-scale LED business.

In our base case, LED retrofits could achieve 37 percent penetration by 2015, a scenario largely in line with industry expert consensus of 30-35 percent. This rate can be accelerated by the comprehensive approach we have indicated to the five main barriers: operational improvements to drive down costs, improved marketing of LED products in stores, establishing third-party lighting providers for the commercial markets, successful attraction of government support via subsidies, and increased focus among manufacturers on LED's potential.

By overcoming these five barriers the industry could drive a 5-year LED retrofit adoption rate above 50 percent. At that point, LED would become the dominant technology in consumer and commercial lighting, providing the industry with a crucial new source of profits for years to come.

LUMEN EFFICIENT DEVICE

The "Solar Tree" is a collaboration of Artemide and Sharp designed by Ross Lovegrove.



[IC] [OPTO] [LED] [LCD] [RF]

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LED momentum builds at annual Street and Area Lighting Conference

Presentations at the IES Street and Area Lighting Conference were predominantly centered on LEDs, and there were first-hand opportunities to view SSL installations, reports **MAURY WRIGHT.**

In late September, the Illuminating Engineering Society (IES) held the annual Street and Area Lighting Conference (SALC) in Huntington Beach, California with a crowd of more than 600 attendees focused increasingly on LED-based street lights. Attendees from utilities, municipalities, lighting manufacturers, and design houses shared information on how to successfully migrate to energy-saving SSL technology. Moreover, the presentations made it increasingly clear that SSL can deliver superior lighting despite obstacles that still must be overcome.

The most compelling presentations at SALC were all focused on actual LED street light installations. Californian cities including Huntington Beach, Los Angeles and San Jose made presentations, and we'll get into some of that detail shortly. Moreover, both the Electric Power Research Institute (EPRI) and the Climate Group's LightSavers Global Consortium presented trial data. The exhibits at SALC are limited by the IES to a relatively small area, but LEDs also dominated that space.

The Los Angeles LED project

Following SALC, the US Department of Energy (DOE) took advantage of the crowd in town for SALC week to hold the first workshop of the DOE Municipal Solid-State Street Lighting Consortium. The City of Los Angeles Bureau of Street Lighting hosted the workshop. On Thursday night prior to the workshop, Bureau Director Ed Ebrahimian hosted a tour of some Los Angeles LED installations for a bus full of representatives from municipalities involved in LightSavers and selected media representatives.

MAURY WRIGHT *is the Senior Technical Editor of LEDs Magazine.*

FIG. 1. HPS street lights on Hoover Street in Los Angeles near the University of Southern California campus leaves dark areas along the major street.

Let's start our dive into SALC week details with the Los Angeles project, which is the largest LED street-light project in the world. The city has around 210,000 street lights and plans to retrofit 140,000 with LEDs – ultimately all of the standard cobrahead lights. As Ebrahimian explained, the Bureau has already installed more than 20,000 LED street lights.

Prior to the start of the LED project, Los Angeles used 190 million kWh per year to power its street lights at a cost of $17 million annually. According to Ebrahimian, the city's goals include 40% energy savings and a reduction in maintenance costs. When the 140,000-fixture program is complete, the Bureau expects to save $10 million annually, comprising $7.5 million in energy and $2.5 million in maintenance. Moreover the project will reduce carbon emissions by 40,500 tons.

Ebrahimian's team has developed a comprehensive specification to guide purchases of LED luminaires (the specification is available at http://bsl.lacity.org). Key specifications include 4300K color temperature, 6-year warranty, 70% of initial lumen output at 50,000 hours, and 40% energy savings.

Energy and cost savings

The program has already yielded some data that indicates the energy savings are achievable and that installation costs are coming down. With 20,000 units installed, the LEDs are actually delivering an energy saving of 55%, as opposed to the projected 40%.

Ebrahimian also discussed the cost of the retrofits. Los Angeles is currently paying just under $500 per installed LED street light. The materials, including the luminaire, make up the bulk of the cost, coming in at $423. Engi-

FIG. 2. The LED retrofit on Hoover Street delivers more uniform light and better visibility.

neering adds $30 and labor adds $43.

The Los Angeles Bureau has its own engineering and installation crews. The Bureau had expected that crews could each handle 20 retrofits per day, but in actuality each crew is managing 30. The Bureau had originally projected a seven-year payback period. Now Ebrahimian expects the payback to drop to six years or less based on increased energy savings and declining installation cost due both to the efficient crews and to steadily-declining SSL fixture prices.

Note also that the Los Angeles installation exclusively uses luminaires equipped with ROAM network connectivity for remote monitoring. The remote monitoring should add to maintenance savings because the Bureau can easily detect failed luminaires; however, the City has yet to experience failure of an LED luminaire. Moreover, the city plans to move to dimmable luminaires in the future, which could also multiply the energy savings.

Ebrahimian also presented positive data points about the light quality in the LED installations. The Bureau had expected some negative feedback from the community, but most has been very positive. The LED luminaires are delivering more uniform illumination, and Ebrahimian referred to the results as the "carpeted effect" where very few dark spots are seen on the street. The before and after photos of the installation in Hoover Street in Los Angeles (Fig. 1 and Fig. 2) show the lack of uniformity with the previously-used HPS lights. Moreover, the tour Ebrahimian hosted after SALC seemed to confirm, to the naked eye, claims about superior visibility and uniformity in LED-lit areas.

There was one other point of feedback that's not quantified but is impressive none the less. Ebrahimian was asked if the LED lighting had resulted in any measurable decrease in crime. He responded that he is planning to specifically study that angle going forward. But he reported that the officer in charge of Los Angeles police helicopters estimated a 5-fold improvement in visibility from the air.

Measured data counts

While some of the Los Angeles results include directly-measured data, Tom Geist, Senior Project Manager at EPRI, presented a precautionary tale of potential problems with SSL that emphasized the need to measure everything about a transition to SSL. Regarding SSL in street lighting, he said, "Show me the data verifying energy savings. Show me the data for [SSL] being equivalent or better lighting. Show me the data that LED street lights are reliable."

Geist's point is that the industry should have concrete answers to all of these points before moving to large-scale LED deployments. He detailed a number of concerns starting with the longevity of installed products. He points out that the first mercury-vapor street lights were installed in 1938, and that 13% are still installed according to the DOE. Geist said, "If LEDs are adopted they could be with us for a long time. The decisions we make now we will have to live with for a long time."

Geist has other concerns related to the driver electronics. He believes that the LED drivers being deployed today aren't as efficient as power supplies used in other products. For example, the power supplies being used in PCs today must be 92% efficient over the range of 10% to 100% loading. Yet EPRI evaluated LED drivers operating from 120V, 240V, and 277V inputs and found in each case that driver efficiency dropped considerably at light loads.

The issue here is that a key energy-saving attribute of SSL is the ability to dim the lights. But, according to the EPRI data, typical drivers are only around 70% efficient at 20% loads whereas efficiency approaches 90% near full load. The LED driver typically represents 10% of fixture energy usage. Geist sees drivers as wasting energy needlessly, and impacting the energy you might save by dimming the LEDs. Geist recommends "the use of specifications to force improved efficiency."

Geist sprung a few other surprises on the SALC audience. According to EPRI tests, LED fixtures require more power during the winter with colder ambient temperatures. He reported that some fixtures required more than 6% additional power in cold temperatures. Geist couldn't explain the cause, and cold ambient temperatures are generally considered a good thing for LED luminaires. Questioned after his presentation, Geist said that the LEDs may also be brighter in colder ambient environments.

The 480V AC supply that is used to power some street lights was a final obstacle noted by Geist. He stated that the autotransformer required to step-down the AC voltage to 277V increases fixture power consumption by just over 7%. Of course, street-light designs could move to a power supply designed to work at a higher line voltage and mitigate that power increase to some degree. Moreover, some street light installations already use a lower line voltage.

Scotty the EPRI rover

Despite the obstacles of which he warned, Geist ultimately presented positive results from some EPRI tests. EPRI is in the process of planning and conducting test installations at upwards of twenty US sites in collaboration with utilities. Some have already produced results and the agency is using an innovative remote-controlled vehicle called Scotty to gather the data (Fig. 3).

EPRI has modified and augmented a

FIG. 3. The EPRI Scotty remote-controlled rover can automate the measurement of light levels based on a virtual rectangular grid comprised of squares at street level.

Photo courtesy of Clanton & Associates

FIG. 4. Small objects of different colors, shown here under low-pressure sodium lights, helped San Jose measure detection distance under various light types.

model vehicle for the express purpose of measuring street-light performance. The rover is equipped with photopic and scotopic light sensors. Moreover the vehicle carries a differentially-augmented GPS receiver with accuracy at the centimeter level. And the vehicle has a Wi-Fi node and small computer system that takes light measurements and transmits them to a notebook computer.

EPRI deploys Scotty to automate the capture of measurements on a grid pattern at street level. Most of the tests to date have captured data in the center of each 5-foot-square element of a rectangular grid although the system could support 2-foot granularity. According to Geist, EPRI staff have to perform a 3-point calibration at a test site, and Scotty and the notebook computer automatically handle the remainder of the data gathering.

Geist presented data from a couple of test sites where Scotty has been deployed. In Reed Hook, New York, EPRI has a trial where a 147W LED fixture is replacing a 220W metal-halide luminaire. Based on data gathered by Scotty and measured energy usage, the LED fixture will yield 30% energy saving and what Geist termed "much improved lighting." And in this case the much improved lighting statement is based on the fully-characterized lighting grid evaluated for both types of light by EPRI software that processes the data gathered by Scotty.

When light levels lie

Of course not everyone is so sure that the street-lighting segment should be solely focused on light levels. Laura Stuchinsky, Sustainability Officer at the City of San Jose, and consultant Nancy Clanton of Clanton & Associates presented recent research that suggests that LEDs can be safely operated at lower light levels.

San Jose had trialed some LED street

A REVOLUTIONARY DESIGN IN LED HEAT SINKS

Experience the next-generation in cooling technology for LED lighting. The Singapore Institute of Manufacturing Technology (SIMTech) has developed revolutionary heat sinks made from a process known as Liquid Forging – that delivers improved designs far superior than conventional heat sinks. With better thermal efficiency, liquid forged heat sinks enhance LED brightness and reliability.

Why well-designed heat sinks are important?

As the need for high-powered LED lighting (which generates significant amount of heat) gains traction, existing light fixtures cannot effectively dissipate heat away from the LED lighting. Hence one of the key challenges of lighting manufacturers today is – thermal management.

When the LED temperature continues to rise, the optical wavelength can shift. A thermallly stressed LED light will also quickly lose efficiency and have diminished lumens-per-watt output, affecting its brightness. If LED thermal management is unable to meet the temperature specifications of the LED, a breakdown may also occur. Other effects of thermally stressed LEDs may include internal solder detachment, damage to die-bond epoxy, lens yellowing, and so on.

This effectively increases the waranty and replacement costs for the LED lighting company and end-users.

Thus, the LED lighting industry needs to develop innovative, low-cost conductive and convection cooling to deliver peak LED lighting performance with improved longevity. And this is made possible with a revolutionary heat sink design – one that hinges on breakthrough manufacturing processes, in order to realise the vision of new, cutting-edge thermal performance.

BENEFITS OF LIQUID FORGED HEAT SINKS

Improved thermal performance

Rapid heat transfer delivers more lumens/watt and enhances the LED lifespan.

- Aluminium wrought alloys conduct heat faster than cast alloys used in die casting. Also by incorporating a copper base, the heat sink achieves 4 times better thermal conductivity.
- Intricate fins and pins deliver a higher aspect ratio, increasing the surface area for ambient heat transfer. With no centre core, heat removal by convection is also improved.
- Porous-free microstructure eliminates air pockets for rapid, continuous heat transfer through the heat sink to the surroundings.

Flexible design

The key to an effective LED heat sink design is to be able to balance both maximisation of heat sink surface area and form factor constraint of light fixtures. Each custom LED lighting design involves the concept of efficiently transferring as much heat as possible away from the LED chip. SIMTech 's liquid forging manufacturing revolutionises the way aluminium heat sinks can be designed and optimises the total surface area of the heat sink.

With a high aspect ratio and the ability to create 3D designs as a single piece, liquid forging is a highly scalable manufacturing process, allowing the creation of intricate heat sinks made of composite materials such as copper and aluminium in a single step. The fins of the heat sink can be combined with a copper base to create a radial heat sink with improved design and better thermal conductivity. The process allows heat sinks and light fixtures to be formed as a single piece, minimising assembly costs, and improving thermal efficiency.

Enhanced finishing

The heat sink can be anodised for a better finishing, which further improves thermal performance by an additional 10 – 15%.

"We can now deliver more brightness on the same board. Our users especially appreciate the smaller form factor that produces so much illumination. Additionally, with a flexible manufacturing process, we can create a wider range of products without incurring extra tooling or materials costs."

Mr Simun Wong, Director, Redd Innolit Pte Ltd

COMPARISON WITH TRADITIONAL HEAT SINKS

Liquid forged heat sinks perform better than current heat sink designs. Some advantages include

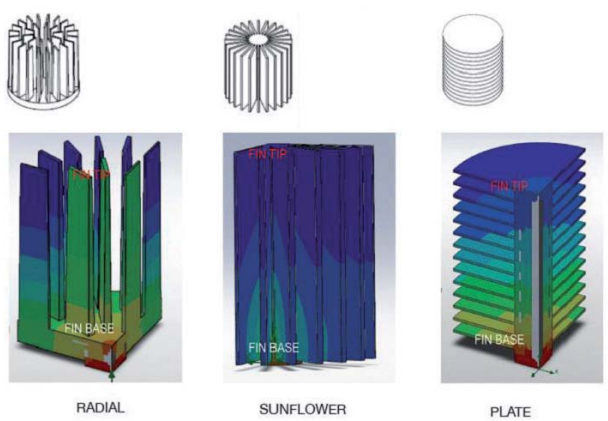
Features	Liquid forged	Die Cast	Extruded
High-aspect ratio	✔	✘	✘
Enhanced heat dissipation	✔	✘	✘
Flexible design (E.g. 3D)	✔	✘	✘
One-step manufacturing with light fixture	✔	✔	✘
Minimum porosity	✔	✘	✔
Anodised finishing	✔	✘	✔
Enhanced aluminium alloy conductivity	✔	✘	✔

Benchmark tests results:

Liquid forged heat sinks deliver better cooling with its unique design. Tests performed using the same heat source on three different types of heat sinks show that a radial fin design – formed by liquid forging – achieves the lowest base temperatures; the lowest temperature difference between the fin base and tip, and the lightest weight. This indicates highly-efficient heat dissipation and much lower thermal resistance than conventional heat sinks.

Heat sink	Fin base	Fin tip	Temperature difference	Weight
Radial	**97°C**	**92°C**	**5°C**	**62g**
Sunflower	102°C	95°C	7°C	119g
Plate	172°C	158°C	14°C	101g

Test performed based on the same form factor of diameter 50mm, height 40mm and 20W power.



RADIAL SUNFLOWER PLATE

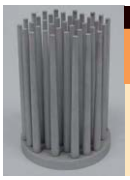
FULL SUITE OF DESIGNS

1. Target LED power: 10W – 12W

Radial – D46			
Material	**Number of Fins**	**Weight (G)**	**Fin Height**
Wrought Aluminium	24	70	≤70mm

Radial – D50			
Material	**Number of Fins**	**Weight (G)**	**Fin Height**
Wrought Aluminium	20	62	≤40mm

Radial – D50 – D60			
Material	**Number of Fins**	**Weight (G)**	**Fin Height**
Wrought Aluminium	20	130	≤40mm

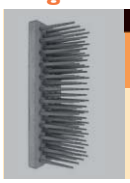


Pin – D46			
Material	**Number of Fins**	**Weight (G)**	**Fin Height**
Wrought Aluminium	37	70	≤70mm

2. Target LED power: 12W – 20W

Radial – D70 – D90			
Material	**Number of Fins**	**Weight (G)**	**Fin Height**
Wrought Aluminium	30	280	≤70mm

3. Target LED power: 20W – 30W



Pin – 225 x 80			
Material	**Number of Fins**	**Weight (G)**	**Fin Height**
Wrought Aluminium	81	440	≤70mm

For More Information

To find out more about our heat sink solutions for LED lighting, contact:

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S&E Commercialisation
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Tel: +65 6478 8431
Email: Joanne_Mosbergen@exploit-tech.com

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lights previously and concluded that the economics of installing the lights wouldn't pay off unless the city could find a way to bolster savings beyond SSL efficiency and dimming. Specifically, San Jose conducted research into the effect of lowering light-output levels. Clanton had worked previously on trials in San Diego, California and Anchorage, Alaska and suspected that color temperature and spectrum issues might come into play. So San Jose pursued a new test that would compare existing low-pressure sodium (LPS) lights with 4000K induction lights, and 3500K, 4000K, and 5000K LED lights.

The trial included a detailed evaluation by volunteers based on an extensive list of questions. The respondents clearly disliked the LPS lights. San Jose had originally installed LPS to appease the nearby Lick Observatory. The volunteers greatly preferred the white or broad-spectrum LED lights with the warmest 3500K luminaire being the most preferred.

The evaluations were followed by tests conducted by Ronald Gibbons of the Virginia Tech Transportation Institute. Gibbons and his team equipped a car with a GPS system and meters for luminance and illuminance measurements. Volunteers that ride in the car have a push button to signal the data-gathering system when the volunteer spots a small-target test object. The test determines what is called the detection distance.

FIG. 5. The Kim street light mounts small groups of LEDs inside a MicroEmitter reflector module (inset) that directs light to a larger reflector to form the desired beam pattern.

Small object detection

The photo in Fig. 4 depicts the colored test objects under LPS lights. In the actual tests, the objects were located randomly along the test site. Gibbons' team verified that the tests were run under each light source at equivalent levels of light output.

The team conducted identical tests two consecutive nights. The first night all of the lights were operated at levels equivalent to the legacy LPS levels. The second night the light levels were reduced 50%.

The team graphed the results of detection distance relative to energy usage in watts per linear foot. The quick result summary is that the LED luminaires generally offered the greatest detection distances, with the spread of all tests in the 40 to 70 meter range. At the high-setting used the first night, the LPS lights used about 2.1 watts per linear foot while the LEDs came in around the 1.1 level.

The more significant results came the second night. The LEDs at 50% light level still afforded detection distance in the 60-meter neighborhood while the LPS distance dropped to 40 meters. Moreover, the energy consumption in the LED lights dropped to 0.5 watts per linear foot whereas the LPS figure remained over 2.0.

"We can detect objects at greater distances," stated Clanton. "The greater the spread in wavelengths, the better the detection." Clanton can't attribute the advantage of what she calls broad-spectrum light to a specific physiological effect for now, but she points out that Gibbons' team is doing further research.

Meanwhile San Jose hopes to use the findings to derive further energy savings with LEDs. Stuchinsky even described how San Jose will meet IES guidelines while dimming some lights. Some roadways that are considered high-capacity at rush hour are actually low-capacity later at night. So San Jose will used dimming technology to change the levels corresponding to different IES specifications at different hours. Clanton stated, "This opens the door to adaptive standards."

Utility LED tariffs

Still, Stuchinsky needs a break from the local utility to make SSL pay off. Today most utilities bill a fixed rate per street light that's calculated rather than measured. LED street lights with adaptive controls require cooperation by the utility to lower rates. Remote monitoring systems such as those being used in Los Angeles and San Jose can provide the metered power usage. But most utilities are moving slowly in developing new tariff levels.

Indeed, SALC included a "Utility LED Tariff Panel" on Tuesday morning with participation by We Energies of Milwaukee, WI; Pacific Gas & Electric (PG&E) headquartered in San Francisco, CA; DTE Energy of Detroit, MI; and Puget Sound Energy of Bellevue, WA.

Generally the panelists conceded that utilities are lagging behind the technology when it comes to tariffs for LEDs. PG&E presented by far the most proactive data but noted that there is no standardization among LED fixture types and the energy used. The utility for now is maintaining fixed-rate billing with new tariff levels created at 5W incre-

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ments. Clearly, however, the best answer going forward is remote metering.

There was also a presentation on incentives available to organizations that install SSL in street-lights and other lighting applications. Tom Coughlin, Program Manager of Energy Products for National Grid (a New England utility) described how taxpayer-funded energy-efficiency programs work. Moreover he discussed organizations such as the Design Lights Consortium that National Grid uses to gauge whether an SSL product qualifies for purchase incentives. For example, the utility offers $100 to $150 rebates for SSL luminaires purchased for deployment in parking garages.

Coughlin also discussed some experiences with SSL gathered in the field and how luminaires perform to their specifications. That led to an audience question on driver reliability and whether the driver should be covered under warranty. About failed drivers, Coughlin said, "We assume it will get replaced just like a ballast."

Street-light luminaire update

There was little new in the exhibit hall given that several major lighting trade shows took place recently. However, we did see a street-light design from Kim Lighting (a Hubbell Lighting Company) that we didn't mention in our recent story on street-light beam patterns (www.ledsmagazine.com/features/7/9/8). The Kim design (Fig. 5) mounts small groups of LEDs inside a reflector module that the company calls a MicroEmitter. The modules direct light at additional reflective surfaces to form the beam pattern. It's tough to judge the effectiveness of a design on an exhibit floor, but surely the Kim design has a thermal advantage with each MicroEmitter being bolted to aluminum and also serving as a heat sink.

Discussions at the conference would indicate that there is still much debate as to which luminaire designs work best. Los Angeles is currently installing BetaLED and Leotek luminaires. But Ebrahimian points out that the Bureau will continue to evaluate the latest products, and is looking for superior performance and low price. According to Ebrahimian, his team currently is in a third round of such evaluations, examining six new luminaires. Judging from the products being tested during a brief lab tour, both Kim and General Electric luminaires are part of the new evaluation, presumably alongside the incumbents and two others.

LINKS

Additional coverage of SALC on our website:
www.ledsmagazine.com/news/7/10/11 and www.ledsmagazine.com/news/7/9/24

advertorial

Optiled LED ARRAY Brings Energy-efficient Lighting Solutions to Enterprises

Reliable performance recognized by international awards and world-class exhibitions

LED lighting has been gaining recognition quickly in the past few years, thanks to its high energy efficiency, long life spans and environmentally-friendly features. Although these benefits should encourage widespread usage among enterprises of all kinds, many remain hesitant to fully adopt this new lighting solution. Peter Chan, managing director of Optiled Lighting International Ltd., understands the concerns of business decision makers. "LED lighting solutions can help enterprises save on operational costs, but lighting is a mission-critical infrastructure for business operations, especially those in the retail sector," he said. "For this reason, some decision makers are afraid to introduce new technologies that might lead to new business risks, and would rather choose to take a 'wait and see' approach when it comes to LED lighting."

International Awards and Recognition

Nevertheless, the performance and reliability of LED lighting solutions have received worldwide recognition. Optiled's LED ARRAY product series recently won the Design Plus award at the Light+Building Fair 2010 in Germany. Out of 140 competing companies, Optiled was the only one from Asia to receive this prestigious award. Rigorous judging criteria included overall concept and design quality, innovativeness, technical quality and eco-friendliness, affirming that Optiled's products have achieved the highest international standards in all of these areas.

> "We are delighted about winning the competition against such a strong group of world-class enterprises and receiving this international award," said Peter Chan, managing director of Optiled.

The award-winning LED ARRAY product series features a number of innovative technologies to tackle problems arising from traditional lighting solutions. For example, LED ARRAY reduces heat by replacing multiple LED lighting sources with a single high-power Cree LED lighting source, coupled with the most advanced thermal heat-pipe technology. It also uses advanced indirect lighting technology to strengthen brightness control, and minimize light leakage and glare. This versatile product underwent two years of research and development before being introduced to the market as the ideal and most versatile lighting solution for a wide range of applications.

In addition, Optiled is also garnering attention at the international level with its participation at the World EXPO 2010 Shanghai. Optiled is the designated LED lighting fixture provider of the United Nations Pavilion, and its LED lighting solutions are also used in the Japan Pavilion, the Tibet Pavilion, the Shaoxing Restaurant, as well as the United Arab Emirates Pavilion.

"By having our LED lighting products installed at various World EXPO pavilions in Shanghai, our company's image and reputation has received a significant boost," said Peter Chan. "Most importantly, these achievements demonstrate the excellent quality and reliability of Optiled's LED lighting solutions. The fact that our products are used in key national projects should clear up any doubts that enterprises may have about choosing Optiled."

Case Study: Local Retail Application

Optiled LED lighting solutions are widely used by large corporations, including restaurants and bookshop chains. One fine example is a renowned jewellery & watch retail shop located in Central, Hong Kong. The shop had been using traditional AR111 spotlights to illuminate its 2,300-square-meter floor area, which consumed 33,523 kWh electricity each year, amounting to an annual electricity cost of over HK$30,000. In order to reduce energy expenses and the cost of making frequent light-bulb replacements, the shop switched to Optiled's LED ARRAY series LED lighting solution. Specially designed for retail applications, LED ARRAY's benefits include lower power consumption than conventional lighting with energy consumption and cost savings of up to 80 per cent. In addition life-spans

are at least eight times longer than for traditional AR111 spotlights, directly reducing the cost of replacing illumination equipment for the storefront. The high Color Rendering Index (CRI) of LED lighting provides yet another benefit to the shop by bringing out the true color of the displayed merchandise, indirectly increasing its appeal to customers.

"LED lighting not only helps enterprises save energy and replacement costs, but also offers intangible benefits, such as an improved corporate image, by gaining the recognition of clients and partners that are concerned about environmental protection," says Peter Chan. "For example, jewellery & watch retailer mentioned above will reduce carbon dioxide emissions by 18,158kg (18 tons) annually by switching to LED lighting, which is equivalent to the amount of carbon dioxide absorbed by 288 trees in 40 years*. This kind of environmental impact would definitely impress consumers concerned about the environment."

Facts about the local jewellery & watch retailer lighting upgrade

	Traditional AR111	LED Optiled ARRAY	Savings
Annual Energy Consumption	33,523kWh	7,207kWh	26,316kWh (about 80%)
CO_2 Emissions	23,130kg	4,972kg	18,158kg (about 80%)
Annual Energy Cost (HK$)	$33,523	$7,207	$26,316 (about 80%)

To help corporate customers increase their understanding of LED lighting solutions, Optiled offers a LED Lighting Simulation Service. Using advanced 3D rendering technology to produce customized three-dimensional drawings in full color, the service simulates the result of using LED lighting and provides a data analysis that meets general lighting requirement needs. Evaluation of the difference in energy savings achieved by switching from traditional to LED lighting is also provided. This service not only enables clients to preview the Optiled LED lighting design and plan more clearly, but it is also flexible enough to allow modifications according to specific needs of different enterprises. In addition, the service can help enterprises calculate the energy savings after switching to LED lighting solutions, as well as when the investment would break even or earn positive returns.

* source: http://www.climateers.org/chi/contents/climateer_calculator.php

standards | **UPDATE**

Non-directional luminaires require new testing procedures for LED light engines

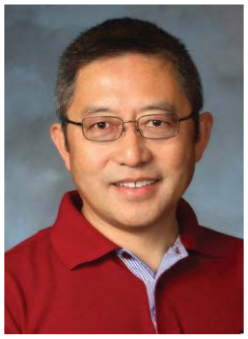
In his latest column on standards, **JIANZHONG JIAO** explains why changes to the Energy Star program will require new standardized procedures to evaluate the performance of LED light engines.

As solid-state lighting (SSL) technology advances and becomes increasingly used in luminaires, the lighting industry has identified a need for more definitive standards to guide the design and development processes. The recently-drafted US Energy Star Program Requirements for Luminaires identifies two categories of luminaires: directional applications and non-directional applications. To qualify for the Energy Star Program, a non-directional luminaire must be tested at the light-source level (namely, the LED light engine) rather than testing the entire luminaire. This new requirement has put the lighting industry in a position to gain a better understanding of LED light engines.

What is an LED light engine? According to the ANSI standard "Nomenclature and Definitions for Illuminating Engineering" (ANSI/IESNA RP-16 Addendum B), it is "an integrated assembly comprised of LED packages, components or LED arrays (modules), LED driver, and other optical, thermal, mechanical and electrical components. The device is intended to connect directly to the branch circuit through a custom connector compatible with the LED luminaire for which it was designed and does not use an ANSI standard base." It should be noted that an LED light engine is not an LED lamp; although the light engine may be replaced, it does not have a standard socket base.

Non-directional and decorative lighting

Recently, LED light engines have been used for various SSL products, notably for residential light fixtures and in lighting fixtures that have decorative features. Overall, the Energy Star program classifies these fixtures as non-directional applications. Because non-directional luminaires are not meant exclusively to provide illumination for visibility, the lit and unlit appearances are important factors for consumers' acceptance of these products. Desired performance may include illumination uniformity, which is often achieved with diffusers; or sparkling effects, which can be achieved using prisms to scatter the light. Traditionally, non-directional luminaire manufacturers do not provide luminaire-level photometric data; they generally specify only the type of lamp and maximum allowable wattage. Also, consumers typically rank aesthetics more highly than technical criteria such as total lumen output and efficacy.



The intent of the Energy Star Program is to recognize energy savings while maintaining consumer acceptance and adoptability. When energy-efficient LED light sources are introduced, it is challenging to determine how to test non-directional luminaires that may have decorative features, while also evaluating and distinguishing their power-saving benefits. The method of luminaire-level efficacy (lumens per watt) may not be appropriate for use in this situation, given that decorative features may sacrifice efficacy for aesthetics, and may simply not be quantifiable. Energy Star requirements aim to evaluate and qualify the performance of the luminaire purely as a light source, so that the energy-saving benefits can be measured while its decorative features remain a matter for the consumers, end-users and the market to judge. Reliance on Energy Star alone would not best serve applications which are primarily decorative or aesthetic, for example in retail or artistic displays where the visual effect is the highest priority.

Testing LED lighting engines

This new Energy Star requirement leads to an urgent need to have industry-standardized testing methods for LED light engines. Currently, IESNA TPC (Testing Procedure Committee) working groups are developing LED light engine related standards. The first standard is to test LED light engine photometric behavior, or, more simply stated, light output, for its temperature dependence. As we know, the light output from LEDs

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decreases when temperature increases. If an LED light engine is assembled into different non-directional luminaires, each may have different thermal impact, and in turn the luminaires' performance will be affected. Therefore, luminaire manufacturers must be knowledgeable of the LED light engine's temperature-dependent behavior prior to luminaire design and assembly.

The standards that are currently being developed will also provide recommendations for the procedures involved in performing reproducible measurements of LED light engines at any temperature. These measurements include temperature, total luminous flux, electrical power, and chromaticity. The existing IESNA LM-79 is a standard testing procedure designed to capture LED light engine photometric, colorimetric and electric characteristics at room temperature. The new LED light engine testing standard requires the LM-79 test to further capture LED light engine characteristics at two additional elevated temperatures. By doing so, the temperature-dependence characteristics for an LED light engine will be more clearly identified.

By establishing standard testing procedures, luminaire manufacturers are better able to gauge the future performance of their design in the early stages of development. With information from three temperature points (room temperature, and two additional elevated temperatures), the users of the testing report should be able to plot the LED light engine temperature dependence, and then predict its behavior at any other given temperature, commonly known as the data interpolation or extrapolation (within limits). By using the test results and prediction method, luminaire manufactures should be able to use the "in-situ" temperature status to select the characteristics of an LED light engine when conducting luminaire-level performance design.

Another new IESNA standard under development is a recommended procedure to test lumen maintenance of LED light engines. The current IESNA LM-80 standard covers LED packages, arrays or modules, where drivers and heat-sinks are not part of the test. Because the LED light engine is an integrated light source, its lumen-maintenance characteristics may not be the same as the LED packages used inside the light engine.

These new LED light engine testing standards will be essential tools for the Energy Star program to qualify the performance of non-directional LED luminaires.

LINKS

LED lighting community benefits from ongoing standardization efforts
LEDs Magazine April 2010, p59: www.ledsmagazine.com/features/7/4/7

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standards | **PRODUCT SAFETY**

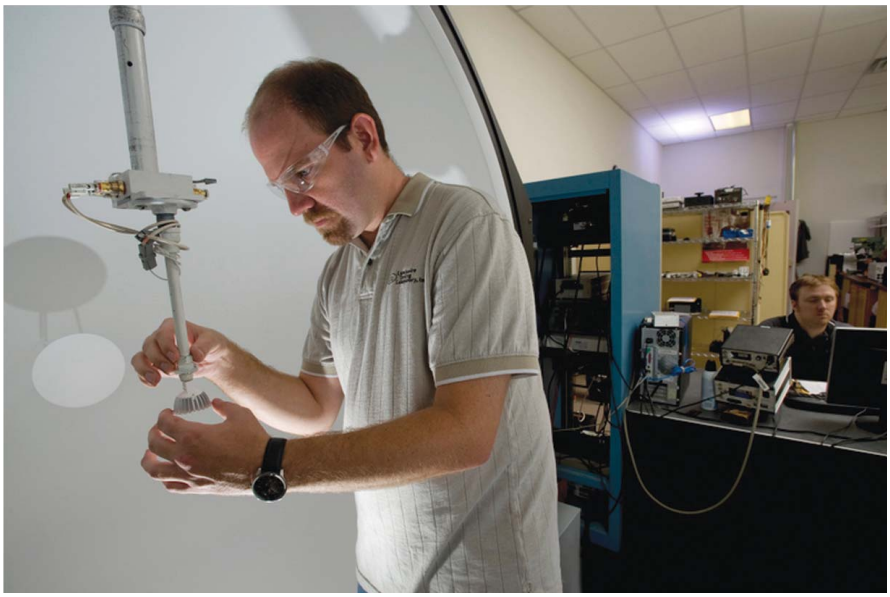
LED product safety standard requires ongoing updates

The UL 8750 product-safety standard has established a set of requirements for LED-based lighting products and the components needed to operate them. However, maintaining the standard during this period of rapid technological advancement is a daunting task, says **TOM BLEWITT.**

Rapid advancements in LED technology are transforming the lighting industry. In what appears to be an overnight shift from traditional lighting designs using incandescent, fluorescent and high-intensity discharge (HID) light sources, new lighting designs using a more energy-efficient LED light source are rapidly becoming the wave of the future. This is truly an exciting yet challenging time for the lighting industry, as well as for commercial and residential lighting consumers.

The pace of development of LED technology, the potential for light sources to be unbounded by conventional shapes and installation constraints, and the environmental regulatory driver assuring LED technology's rapid adoption by the market, is likely to be almost as transformational as the introduction of the original incandescent light bulb. As design and manufacturing professionals have geared up to meet the challenges of the technology, so have the standards professionals.

The US lighting product safety standards have collectively been among the more actively-maintained documents within the larger spectrum of product safety standards. Frequent and dramatic changes in standards have been driven by innovations in fluorescent, low-voltage, induction, electroluminescent and photoluminescent lighting technologies. So too have harmonization initiatives with Canada and, more recently, Mexico. To a large degree, the changes in standards have worked within the existing paradigm of lighting. That is, light sources are a consumable and replaceable component, manufactured in standard sizes that are coordinated with the portable and fixed luminaires in which they are used.



Testing of LED replacement lamps takes place according to the UL 8750 standard, which must be maintained and updated as the technology continues to develop.

Luminaires are typically long-lived, only replaced when they wear out or where they conflict with the current décor of the occupancy. For lighting designs using traditional light sources, lampholders, lamps and ballasts are sold as replacement parts to extend the life of luminaires. The safety standards take this into account with their reliance on industry specifications.

Interchangeability

American National Standards Lighting Group (ANSI/ANSLG) standards provide industry specifications to assure interchangeability of parts. Several examples are the ANSI/ANSLG C82 series of standards for fluorescent and HID lamp ballasts, the ANSI/ANSLG C78 series of standards for incandescent, fluorescent and HID lamp types and the ANSI/ANSLG C81 series of standards for lamp bases and lamp-holders. Independent of the manufacturer, an incandescent screw-type lamp-holder such as an E12 Candelabra lamp-holder will, within tolerances, reliably support a candelabra screw-base lamp. Likewise, a G13 medium bi-pin fluorescent lamp-holder will reliably support a medium bi-pin T8 fluorescent lamp. This control of the fit and interchangeability of lamps and holders ensures a good electrical connection.

The marking on listed ballasts also facil-

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itates the substitution of these devices in luminaries, particularly those used in environments requiring special protection features. For example, a listed "Class P" ballast, provided with integral overheating protection, can be substituted in a recessed luminaire with an equivalent listed ballast marked "Class P" without degrading the thermal protection the original luminaire afforded to adjacent building materials. Likewise, a listed "Type CC" ballast designed to minimize arcing of loose lamp contacts can be replaced in a refrigerated commercial cabinet with an equivalent listed ballast marked "Type CC," without degrading the protection against potential loosening of the lamp due to vibrations anticipated under normal use.

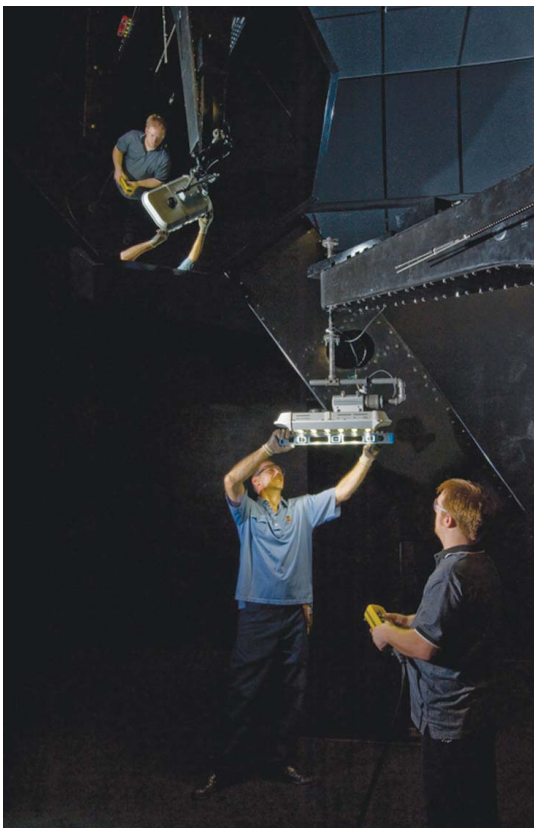
Development of UL8750

Early forms of LED lighting technology have leveraged the more mature existing light-source technologies, and the standardization they enjoy, to gain a market foothold. This is especially the case for incandescent lamp replacements for existing luminaires. UL recognized that, due to the cost and effort to change the installed base of luminaires in use today, these light-source replacement technologies would be around for a long time. UL therefore began the process to develop and document requirements for these LED lamps and the components needed to operate them. These components include power supplies (known by the industry as LED drivers) and other solid-state circuitry collectively referred to as LED controllers.

Beginning in January 2007, several issues of the UL Outline for Investigation for "Light Emitting Diode (LED) Equipment for Use in Lighting Products (Subject 8750)" were published. They were the first of their kind and represented an ongoing effort to capture safety-based certification decisions and disseminate them to the broader marketplace for consistency and predictability.

In May 2009, the proposed First Edition of the UL Standard for "Light Emitting Diode (LED) Equipment for Use in Lighting Products, UL 8750," went out for review and ballot to the UL 8750 Standards Technical Panel (STP). There was consensus on the proposed document and the first edition of UL 8750 was approved and published as an ANSI standard on November 18, 2009 (www.ledsmagazine.com/news/6/11/34). The UL standard benefited from the knowledge and contributions of many industry and other stakeholder experts who volunteered their time and expertise.

The UL 8750 STP is now responsible for the daunting task of maintaining the standard during this period of rapid technological advancement. The second meeting of this STP was held in June 2010 and was attended by 42 industry representatives. It is important for the industry to work together and keep UL 8750 current on this very rapidly developing and important lighting technology. The focus of the STP meeting was to work together and discuss future proposals and revisions to UL 8750. Over 58 technical topics were discussed, with the vast majority involving specific standards-revision proposals submitted by both industry members and UL staff. These proposals, once fully developed, will be again sent out to the STP and industry for review and ballot. Additional STP meetings will be held as the need arises.



In its development, UL 8750 has benefited from the knowledge and contributions of many industry and other stakeholder experts who volunteered their time and expertise.

Future developments

Looking forward, the committee will need to consider how some form of standardization can be implemented to support the repair and replacement markets. Can LED drivers have standardized operating features and ratings to facilitate like replacement and interchangeability, much like that which exists today for Class P fluorescent ballasts? Compatibility of dimming technology with LED luminaires will also need to be addressed. So too will the interface with Smart Grid technology or other forms of energy management and security technology.

One of the potentially more challenging needs involves luminaires that literally are "out of the box." These utilize OLED and other technologies that are not confined but, instead, take any form and size that the imagination and manufacturing technology will permit. The present luminaire product-safety standards have accommodated trapeze and landscape lighting, and there is a published "Outline of Investigation for Suspended Ceiling Grid Low-Voltage Lighting Systems (Subject 2577)" that similarly considers power distribution to luminaires outside the conventional building wiring. However, power distribution to a lighted wall, ceiling, handrail or window – and wherever else it may be possible to illuminate from – may require new thinking. Flame spread of thin materials installed over a large surface may also need to be considered, and so on.

Fortunately, UL's STP 8750 has demonstrated that a large group of experts, representing a range of interests, can come together and reach consensus on important and challenging LED lighting issues. They have a large job ahead of them to do what their forebears did many years ago when they developed the standards for incandescent and then later fluorescent lighting.

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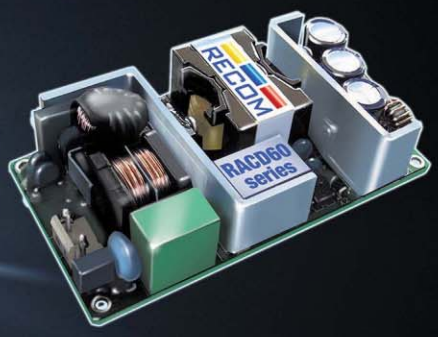

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controls | LIGHTING NETWORKS

Network layers pave the way to adaptive lighting controls

Adaptive lighting control systems will be key to maximizing the energy efficiency of SSL, and network technology will form the foundation for such intelligent lighting systems, says **MAURY WRIGHT**.

Intelligent lighting systems that can dim, brighten, or extinguish lights based on occupancy, ambient conditions, or pre-programmed scenarios will maximize energy efficiency. The adaptive-control technology will compound the savings of energy-efficient technologies such as LED-based solid-state lighting (SSL). *LEDs Magazine* has planned a recurring series on lighting control technology that will be presented in the magazine and on our website. But first we'll describe the network and technology layers that underlie intelligent lighting systems, exploring concepts that will recur throughout the series.

We've covered the concept of adaptive controls from the high level including a recent article that featured research from several analysts that projected the benefits of control technology (www.ledsmagazine.com/features/7/8/6). Different analysts suggest that 20 to 40% of the energy used in commercial buildings provides power for lighting. The analysts project that as much as 60% of that energy can be saved through SSL and controls. Intelligent lighting system vendor Digital Lumens goes further, suggesting that in some cases SSL can save 60% and adding controls can bring the saving to 90% (see p.59 of this issue).

It is a fair question to ask why we need a full-fledged network to implement lighting controls. Indeed a simple occupancy sensor in a luminaire could offer energy-saving benefits. But ultimately a network allows much greater savings through more robust control scenarios, remote metering of power usage, and adaptive response to changing conditions. Moreover, network control allows optimal operation of SSL luminaires to extend product life and implementation of preventive maintenance procedures – both can reduce operating cost.

MAURY WRIGHT *is the Senior Technical Editor of LEDs Magazine.*

The seven-layer OSI model

So let's start by considering a model of how computer networks operate. It turns out that lighting-control networks and systems are exactly analogous to the computer networks we use in our homes and businesses. Networks are based on the seven-layer Open System Interconnection (OSI) model, summarized in Table 1, that was crafted by the International Organization for Standardization.

The ubiquitous Ethernet and Wi-Fi networks that we use correspond to the bottom two layers of the OSI model. The physical layer describes the type of wire or wireless connection and how digital data is modulated on that channel. And the data-link layer describes how multiple network nodes reliably share the same communication channel.

The network layer defines how nodes on a network are addressed. Most PC users have heard the term IP (Internet Protocol) address that in the case of a PC identifies the system on a network. Together the network and transport layers allow reliable communications between any two systems.

The top three layers ultimately allow an operating system such as Windows and applications such as Microsoft Word to share data across the network. Word lies at the application layer. The operating system takes care of the presentation and session layers that format data and handle the protocols that ensure two different network nodes interpret the received data in the same way.

The simple explanation of network layers is important going forward in understanding the various lighting-control network technology because as you can see some technologies cross the layer boundaries. Ethernet, remember, covers two layers. Some control-network concepts can cross more layers.

Control network options

A lighting-control network will require both the lower-layer technologies to link control systems, sensors (lighting, occupancy, and others), actuators (switches and dimmers), and luminaires. The network will also require the upper layers ranging from addressing for each node to protocols for data formats and essentially a lighting-control protocol language. Ideally, standardization of the layers would allow products from any vendor to work together.

Table 1. The OSI layer model

Layer	Name
7	Application
6	Presentation
5	Session
4	Transport
3	Network
2	Data Link
1	Physical

To connect the nodes we will have wired and wireless options. Ethernet could be used in some cases, and even Wi-Fi is a possibility. But lower-cost, lower-speed options will likely be used to link the sensors, actuators, and luminaires.

Two likely options for the lower-layer technologies are ZigBee and power-line communications (PLC). Generally, ZigBee is a wireless network that was designed for short-range, control-network applications

although we will see in a minute that ZigBee might be more or less than that widely accepted concept. PLC is a general term for technology that sends data over the existing AC power lines. The HomePlug Powerline Alliance, for example, has defined standards that allow home networks to operate over the installed AC wiring as opposed to using Ethernet or Wi-Fi. Some flavor of PLC could also be used in lighting-control networks – especially since AC wiring already connects switches and luminaires.

ZigBee and the OSI model

Let's get back to ZigBee and discuss the network technology with respect to the OSI model layers. The ZigBee specification is promulgated by the ZigBee Alliance and includes elements that can span every layer of the OSI model other than the application layer.

At the lower layers, the ZigBee specification relies on the IEEE 802.15.4 standard for low-speed wireless networks. The standard defines operation in ISM (industrial, scientific, and medical) frequency bands that are allotted around the globe for license-free wireless operation. The 2.4-MHz band is available in most countries around the globe and is the most broadly used band.

Here we come to the first point about how many ways the term ZigBee might be used. Both IC and module vendors make what they may call ZigBee radios, and indeed their products might be used in ZigBee applications. But the ZigBee specification goes far beyond the radio that often only addresses layer one of the OSI model.

Indeed the ZigBee specification defines how nodes are addressed and communicate. It defines a mesh topology in which nodes can forward or retransmit messages as opposed to requiring that every node is in range of a base station (the way Wi-Fi works).

Presentation layer protocols

The ZigBee Alliance has gone further and added protocol layers – essentially analogous to the presentation and session layers of the OSI model. For example, the ZigBee Alliance has developed ZigBee Smart Energy protocols for so called smart-grid applications including smart meters for residences – a layer 6 protocol.

The ZigBee Alliance is working on a ZigBee Building Automation standard that will essentially define a command language for lighting, heating, security, and other building systems. The idea, again, is that standardization would allow automation applications to control any compatible product and building-level systems could mix and match sensors and luminaires from any vendor making compatible products.

Alas things are never as simple as they might seem. The Building Automation standard is not complete. Moreover any given vendor isn't required to use that standard when it is ready. A vendor with a catalog of sensors and luminaires can use the ZigBee

lower-level network technology yet add proprietary lighting-control protocols.

It's also possible that ZigBee Building Automation protocols could run on other networks. Already the ZigBee Alliance and the HomePlug Powerline Alliance have agreed to use the ZigBee Smart Energy protocols on both wireless and PLC networks, and the same could happen to Building Automation. In fact that might be a good thing as lighting-control networks could mix the low-level physical-layer options in one building network.

Also understand that ZigBee is far from the only network technology for lighting networks – we used it to lay the basics for future articles. There are other open and proprietary protocols. The point is that as we go forward in our series, we will cover components, modules, software, and systems that cross the OSI network layers. We'll explain how each might fit in an interoperable network scenario.

SIL Europe from page 28

The year of the LED module

After defining LED modules and explaining their benefits, Andy Davies of GE Lighting discussed the Zhaga consortium, which is developing standards for LED light engines (the terms module and light engine were used interchangeably in his presentation). As explained in Fig. 4, Zhaga includes the mechnical, thermal, electrical and photometric (optical) interfaces of a module, but does not include internal workings, allowing manufacturers to differentiate their products. Likewise, driver connectivity will be defined, but internal circuitry will not. "Expect the first Zhaga standard in the first half of 2011," said Davies, "and expect more than one standard by the end of 2011." Several standards will meet different market needs, but unnecessary duplication will be avoided.

A key driving factor for module adoption is the need to design reliable luminaires, which requires an understanding of the LED packaging performance under application conditions. "Buying an LED module from a trusted brand can remove much of the risk," said Davies. Using modules that can be upgraded or replaced when necessary adds value throughout the supply chain, he said. For example, luminaires can take advantage of the most current technology, while distributors can hold a smaller number of parts, since each module can serve a wide range of luminaire brands.

Lighting designers & specifiers

Mike Simpson, Technical and Design Director of Philips Lighting UK, looked at how the requirements of lighting designers and specifiers are being met by LED lighting. Explaining the difference between the two groups, Simpson said that "specifiers create light using a calculator while designers use their heart." He said that legislation is driving the move from conventional light sources towards LED alternatives, and that LEDs are replacing existing design solutions and creating new design possibilities. The main challenges are to understand the technology and to specify LED lighting correctly. Among many examples, Simpson described the Rafayel Hotel in London, which has fitted LED lighting throughout, and reduced the carbon footprint per guest from 70 to 17 kg-CO_2/night.

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Intelligent lighting systems drive radical energy-efficiency gains

LED-based SSL can deliver significant energy savings relative to legacy light sources. And as **BRIAN CHEMEL** describes, the savings are compounded substantially with the addition of controls, resulting in an intelligent lighting system.

LEDs are widely acknowledged to be the engines of wholesale transformation of the lighting industry, creating the opportunity to reinvent how lighting is delivered and consumed. Gone are the days of "dumb" standalone fixtures that waste, in aggregate, tremendous amounts of energy. Today's intelligent lighting systems deliver radical energy savings – up to 90% over traditional fixtures – and numerous other benefits as well.

This industry shift is driven by LEDs' native properties – lower energy use and inherent controllability – and because it is now possible to design complete, integrated and intelligent lighting systems which exploit these properties to maximum advantage. Each of these qualities – low energy use, controllability and systems-oriented design – offers the savings opportunities we need to slash the amount of energy that is consumed by lighting.

More efficient light source

The first step toward achieving radical energy efficiency is switching to a lighting technology that uses much less energy to deliver the necessary levels of illumination. LEDs are that light source, providing excellent light quality while reducing maintenance requirements. These characteristics, combined with rapid and ongoing advances in LED efficacy, are fueling the use of LEDs in a range of applications, from low-power residential replacement lamps to high-intensity luminaires for commercial and industrial applications. The savings in these large facilities can be particularly compelling. For example, if a facility replaces 400-watt fixtures with simple 160-watt LED alternatives, they realize 60% power savings. However, the reduction in on-state power usage is only the beginning of the story.

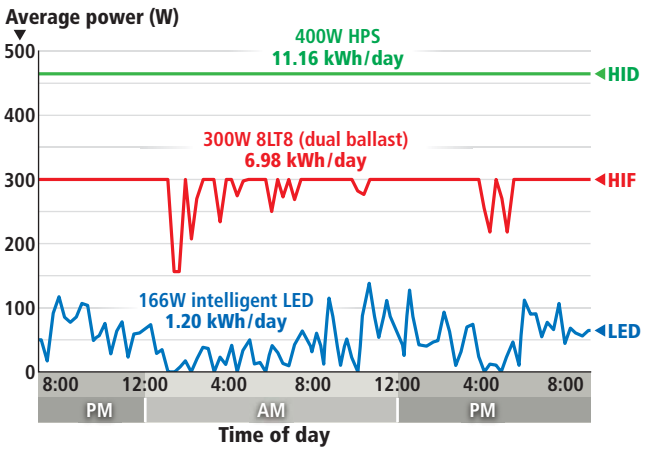

FIG. 1. The graph depicts the average power consumption of a legacy HPS luminaire, a bilevel-switched high-intensity fluorescent luminaire, and an LED luminaire in an intelligent lighting system.

The key to achieving radical efficiency in lighting is to focus on minimizing energy usage, not just steady-state power. An LED luminaire that uses 1/3 the power of its traditional alternative is one thing, but when the luminaire has integrated sensing and controls that automatically limit "on time" to 1/3 of the traditional alternative, the energy savings rise to nearly 90%.

Fine-grained control

From a "green" perspective, the transformational potential of LEDs lies as much in their controllability as in their inherent efficiency; this creates the opportunity for the next level of savings. A recent DOE-sponsored analysis, "Energy Savings Potential of Solid-State Lighting in General Illumination Applications 2010 to 2030" (http://www1.eere.energy.gov/buildings/ssl/news_detail.html?news_id=15806), projects potential energy savings from 2010 to 2030 of 190 TWhr due to the transition to solid-state sources. If a large proportion of the luminaires installed as part of this transition are part of intelligent lighting systems, the energy savings may be twice as large. With such enormous potential energy savings, integrated control is a critical part of the future of lighting. Adopting LED technology without integrated controls and intelligence is leaving a significant percentage of potential savings on the table.

LEDs, as a semiconductor technology, lend themselves well to integration with digital power and control technologies and offer near-infinite controllability. Individual LEDs operate at low voltages, making them far easier to interface with microcontroller-based control, sensing and networking circuitry. They turn on and off instantly, allowing for fine-grained management of when a

BRIAN CHEMEL *is the co-founder and CTO of Digital Lumens (www.digitallumens.com).*

particular fixture is illuminated. They are dimmable to any degree as well. Does a fixture need to be left on at 10% for safety reasons even when no one is around? No problem - in fact, LEDs love to be dimmed and often have higher efficacy at low dimming levels due to thermal effects. In contrast, legacy HID and fluorescent sources are challenged by frequent on/off and dimming, leading to sub-optimal performance and shortened lifespans.

It's trite but true – the most efficient light source is the one that is turned off and used only as needed. To maximize energy savings, the system must know precisely when each light in a building should be off, and what dimming level is appropriate for each light when on. That's where system-level intelligence comes into play.

Metrics that matter

For many lighting buyers, particularly those managing large facilities where lighting is their primary or secondary electricity user, the metrics that matter (once acceptable light levels are achieved) are economic: energy usage (in kWhr, not W), total cost of ownership (TCO), and payback.

Buyers have been conditioned over the years to consider payback as the primary parameter when considering a lighting purchase or retrofit, but TCO is a far superior analysis tool. TCO provides a thorough, unbiased look at all of the cost drivers associated with the acquisition and ownership of a lighting system over a given period of time. Key factors include initial purchase price, energy usage, maintenance, and re-lamping, less any incentives (tax credits or rebates) and other external system efficiencies (e.g., BTU reductions, in the case of chilled facilities if the new lights generate less heat and therefore require less chiller activity to offset).

Payback simply looks at the amount of time until the investment is recouped. This creates a scenario where a lower initial purchase price on a product, even a product with only modest energy savings, can look equivalent to a more expensive product with more dramatic energy savings. It is not until you load in all of the associated costs and consider TCO that you get a truly accurate picture. ◄

Intelligent lighting systems

Dimmable fixtures, occupancy sensors, and lighting control systems have been around for a long time, typically as add-ons to a traditional "dumb" luminaire. Unfortunately, the efficiency benefits from bolting on an aftermarket technology will be constrained, at best, because of traditional light sources' limited ability to actually be managed.

In contrast, intelligent lighting systems integrate a range of technologies to simultaneously decrease energy usage while improving functionality. They also include sophisticated commissioning and configuration tools, sensing, networking and onboard decision-making to deliver light when and where it is needed, at specific light levels appropriate for the task at hand. Complete intelligent systems reduce integration risk by ensuring that all components - intelligent luminaire, sensors, networking, and software - are designed to work together. This is a fundamentally different approach than simply switching dumb fixtures over to run on more efficient solid-state sources.

The key words to focus on here are "integrated" and "system." Rather than a simple, stand-alone luminaire that only provides illumination, intelligent lighting systems deliver completely new levels of functionality while simultaneously driving down energy usage. By operating according to a set of user-defined behavioral rules and responding according to integrated, software-based intelligence, the system supplies light as needed while conserving energy. Because luminaires in an intelligent lighting system share a common communication network, they can communicate with a centralized controller to provide data about usage and area occupancy that can inform subsequent energy-efficiency decisions. They can also receive updated instructions – individually, or as a group. None of these capabilities would be feasible without integration and a systems-based approach.

Intelligent lighting systems rely on a wide range of fully integrated components to minimize energy usage while maximizing functionality. The essential elements include:

Dimmable luminaires: While some fluorescent and incandescent fixtures support limited dimming options, LEDs offer infinite dimming granularity. Their inherent controllability makes them the perfect light source at the core of an intelligent lighting system.

Sensing: In order to deliver the proper amount of light for a particular application, the lighting system needs to know what is going on in that environment. Sensing options can range from simple occupancy or ambient light devices to more application-specific choices such as ambient temperature or vehicle detectors.

Network: Intelligent lights need a way to communicate with each other and central systems. The most capable and commonly used networking platforms are wireless, though powerline carrier technologies are making a strong push. Regardless of the transport mechanism, having a common, standards-based lighting network in place provides current and future integration opportunities.

Centralized controls & software: In order for intelligent lighting systems to work as a system and not just a collection of individual lights, a centralized control device and a software interface are needed. These provide hooks for third-party integration as well as configuration, control and management capabilities.

Measurement and verification: Intelligent lighting systems, with their built-in ability for logging and reporting kWhr usage, can provide measurement and verification data to building owners, utilities, and other interested parties. For the first time, the economic value of integrated intelligence can be measured, analyzed, and managed.

This integrated intelligence and systems-based approach deliver the last level of savings, bringing the cumulative total of savings up to 90% in some applications (Fig.1).

Lighting as a managed asset

While meeting energy efficiency targets is critical, preserving efficiency gains is equally important. Because lighting needs change over time, buildings are at risk of drifting from their original configuration, which can erode energy efficiency savings by up to 15% per year. To ensure ongoing energy efficiency,

the "set-it-and-forget-it" mentality of a one-time commissioning is insufficient. Managers need the ability to re-align lighting delivery with a facility's needs so that they can treat lighting as the managed asset that it is. For example, facilities may have seasonal shifts in working hours that will require a different lighting program. Part of the power of intelligent lighting systems is that they allow the lighting behavior to change according to predefined schedules, and make it simple to re-commission a facility.

Beyond straight energy savings, intelligent lighting systems form the backbone of many "smart buildings." Sensor-enabled fixtures collect data on usage patterns and provide that data to users for measurement and verification. Open APIs enable cross-compatibility and are designed for simple integration with other building automation systems. These capabilities far exceed what most people think about when considering lighting, and are part of the wholesale transformation from simple, energy-inefficient illumination to value-added system.

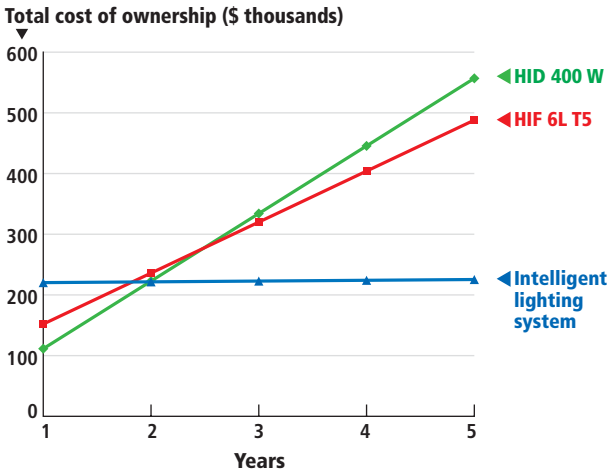

FIG. 2. LEDs in an intelligent lighting system deliver a significant total cost of ownership (TCO) advantage especially when measured over time.

Intelligent lighting systems represent a radical state change in the lighting industry that will have profound implications for both the industry itself and its customers and end users. We are no longer developing standalone islands of functionality that deliver illumination - we are providing illumination sources which tightly align with customers' needs for high-quality light using significantly less energy, while creating the ability to integrate with other systems for additional benefits down the road. The lighting customer, meanwhile, will be learning that system-level intelligence isn't a "nice-to-have" but a fundamental requirement that delivers real, tangible economic and functional benefits.

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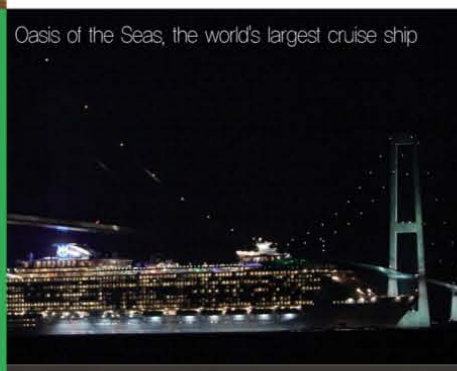

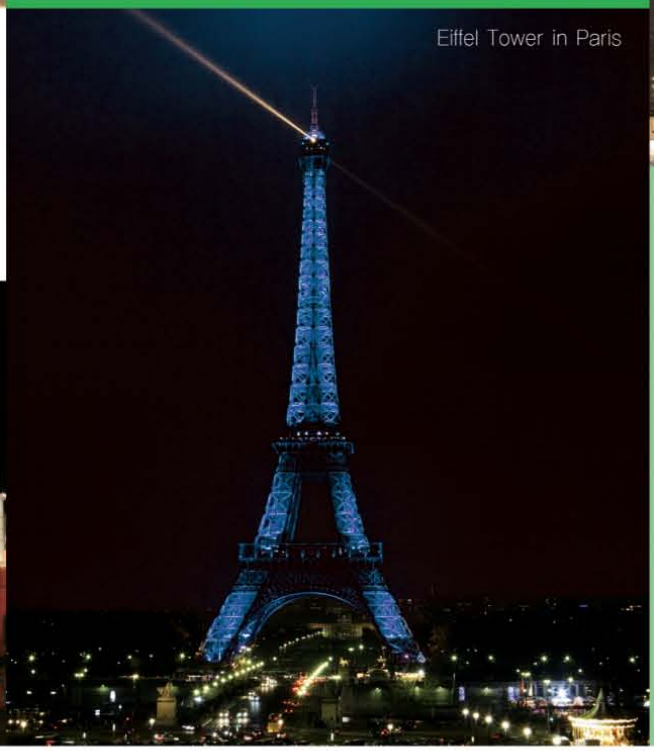

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Miniature spectrometers address challenges of LED research and production

Miniature, portable spectrometer systems can provide accurate in-situ measurements and analysis of LED light sources for a variety applications, including horticulture, according to **JASON EICHENHOLZ, MARCO SNIKKERS** and **DENNIS SCHULMERICH**.

Thanks to the evolution of small, handheld spectrometers, applications such as the testing and binning of LEDs are more easily managed than with previous instruments. Indeed, spectrometers can be deployed to measure LED emission wavelengths as well as brightness and power output. To appreciate why miniature spectrometers are viable tools for LED measurement, it helps to understand the typical performance parameters being measured.

Color and spectral output of LEDs

Although determining the correlated color temperature (CCT) of incandescent light sources is fairly simple, as these spectra fit nicely on a blackbody radiator curve, doing the same for fluorescent and LED light sources is much more challenging. Those sources have very different spectral shapes, making it harder to perform an accurate fit using traditional color-filter-based instruments.

The simplest color meters use diodes or pixels covered by red, green and blue filters. More advanced systems use tristimulus filters. These types of systems work quite well for incandescent light sources but struggle to provide accurate answers for light sources such as LEDs. To detect small color changes, very high color resolution is necessary: resolution a spectrometer can achieve.

A spectrometer captures the light reflected, transmitted, or emitted by a sample and uses a dispersing element to split it into discrete wavelengths, capturing the spectral data for the sample under test.

JASON EICHENHOLZ, MARCO SNIKKERS *and* DENNIS SCHULMERICH *are with Ocean Optics (www.oceanoptics.com).*

FIG. 1. Miniature spectrometers perform well in LED sorting operations, where rapid data acquisition and measurement accuracy are critical.

Because the instrument captures the complete spectral power distribution rather than merely measuring power in observer-specific wavelength bands, the resulting color measurement is more precise and robust. There has been much debate on how much wavelength resolution is needed to make an accurate color measurement, with competing resolution standards from CIE (International Commission on Illumination) or ASTM (American Society for Testing and Materials) varying from 1 nm to 20 nm.

Another standard LED measurement characteristic is color rendering index (CRI). CRI is a scale quantifying the effect artificial light sources such as LEDs have on color perception. Today's CRI scale is problematic as an indicator of color quality, particularly when applied to a white LED that has several peaks in its spectra. CRI is based on only eight reflective samples, all of which have low to medium chromatic saturation. These samples do not adequately span the range of normal object colors. What's more, some lights that are able to accurately render colors of low saturation perform poorly with highly saturated colors.

As standards-setting bodies devise new scales that better reflect a range of parameters – color rendering, chromatics discrimination and the like – researchers and quality-control professionals consider various measurement tools for a range of LED color and spectral output applications.

Advantages of miniature spectrometers

For years, most portable color measurement systems utilized a small, compact spectrometer such as the Ocean Optics USB2000+.

Thousands of these systems have been deployed for testing and binning of LEDs inside high-volume testing machines. LED manufacturers need to test the emission wavelength of each device to ensure the output is within ± 0.5 nm of the specified emission wavelength.

Miniature spectrometers not only provide quantitative data, they assess other metrics like brightness and output power for efficiency calculations. In most cases, it is more cost effective for a high-volume LED user – consider the example of a manufacturer of LEDs used in signage – to test and sort a large number of LEDs into smaller bins than it is to tighten the specifications for the LEDs from the manufacturer. This would be impossible to do without the speed and accuracy of the color measurement from a miniature spectrometer (see Fig. 1).

Let's consider speed: Some LED sorters process as many as 8,000 pieces per hour. Most miniature spectrometers can measure and process spectral data for each LED within 10-50 milliseconds. Spectral data can be quickly digitized and processed by computer to determine dominant and peak wavelength values, CIE color values and irradiance (lumens). Armed with these results for each LED, the sorter can transport each die or chip to the appropriate collection bin for storage.

Also, because the spectrometer has no moving parts, it can more easily withstand the rigors of continuous operation in an industrial setting.

Color resolution is another consideration. Most handheld color meters deliver less than 20 wavelength bands, not enough for accurate or scientific studies. So what if you want to make a high-resolution color measurement, but can't tolerate the size or weight of the laptop or even a netbook computer to make your measurement? The latest miniature spectrometer systems – such as the Ocean Optics Jaz spectrometer – are specifically designed to perform portable measurements and can operate in the field without a PC. The unit can be spectrally and radiometrically calibrated, pixel by pixel, and adjusted for an accurate analysis of a broad range of illumination sources. The instrument also provides an irradiance spectrum and additional calculated colorimetric parameters in the field.

FIG. 2. Measuring the output of LEDs used in greenhouse operations helps growers adjust LED output to optimize plant growth.

Applications in the field...and beyond

LEDs are in use for all sorts of applications, but this one caught us by surprise: LEDs in horticulture. LEDs are configured to stimulate plant growth in greenhouse environments – and their use for such applications is, well, growing. Horticulturists are interested in the effects of light on the growth of their crops, with much analysis of how the intensity of blue and/or red light affects both the growth rate and blossoming of various floral crops.

Until now farmers and horticulturists were limited in their options to control and measure the illumination of their crops. But recently the horticultural industry has been experimenting with the addition of red, blue and white LEDs to existing illumination systems. The idea is to better tune the spectral content to match the needs of the crops. Continuously monitoring the LED emission spectrum with a miniature spectrometer enables growth patterns to be correlated with the illumination spectra (see Fig. 2).

Also, it is important to measure photometric parameters in situ for applications such as street lighting, advertising signage and hospitality lighting. Miniature spectrometers have the advantage of being easily reconfigured for different spectral ranges and resolution requirements.

As LED measurement needs evolve, miniature spectrometer technologies and solutions will continue to adapt and provide accurate, flexible and cost-effective solutions to a host of applications. Capturing and reporting of the spectral data is evolving as well. Color and other measurement values are now available wirelessly on the iPhone, for instance, or can be transmitted over the Internet to a private network. There are a whole spectrum of possibilities.

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Merger of measurement companies brings integrating-sphere expertise under one roof

Labsphere and SphereOptics, two US-based LED metrology companies, merged earlier this year and are now operating as part of Halma, a holding company that is eyeing further acquisitions, as **KEVIN CHITTIM** and **DAVID LEIGHTY** explain.

Founded in the late 1970s by Phil Lape, a well-known photonics entrepreneur, Labsphere was established in the belief that integrating-sphere technology could improve on existing methods for measuring light. Integrating spheres diffuse and homogenize light, thereby improving the accuracy of optical, photometric and radiometric measurements.

Labsphere was acquired by a colorimeter manufacturer in 1995 and sold to Halma plc, a British technology holding company, in 2007. Meanwhile, in 2003, several Labsphere veterans left the company to establish SphereOptics. In January 2010, SphereOptics was also acquired by Halma and merged into Labsphere, bringing the integrating-sphere manufacturer full circle.

A tale of two companies

During the last several years, Labsphere has developed products to meet the increasingly stringent demands to improve the optical characterization of LEDs. Measurement systems for LEDs combine an integrating sphere with electronics, a photometer or spectroradiometer and application-specific software to measure, analyze and report luminous flux, luminous intensity, chromaticity coordinate, dominant and peak wavelength, FWHM and color-rendering index.

Light metrology systems make up approximately one third of Labsphere's rapidly expanding business, a sizable portion of which are specifically for LED characterization. Accelerated LED Life Test Stations (Fig. 1) are used by manufacturers of solid-state lighting products to help assess longevity, reliability and quality.

FIG. 1. An accelerated LED life-test station.

In 2007, Labsphere was acquired by Halma plc, a UK-based holding group of 36 operating companies. Labsphere joined Ocean Optics in the Health Optics and Photonics division of Halma's Health and Analysis business sector. Halma's photonics companies are established brands with technologies and products which generate light, condition light and analyze the interaction of light with substances. Ocean Optics pioneered the field of miniature spectrometers, and applies that technology to a broad range of applications, including the development of LED technology and quality control in LED production.

Reunification

In 2003, ex-Labsphere president Rob Claflin, together with an investor group and several former Labsphere employees, established SphereOptics to concentrate on the design of high-end custom systems for light metrology and remote sensing. SphereOptics' LCS-LED measurement systems were used extensively for single LED measurement in production and quality-control applications.

By late 2009, SphereOptics' original investors were ready to cash out their interests, and the company was feeling the pressure of increased competition from Labsphere. After Halma approached SphereOptics, the acquisition was completed in just three months with relatively little delay and disruption. As competitors, both companies were growing and profitable, with strong

KEVIN CHITTIM *is President of Labsphere (a Halma plc company), and has also held senior management positions at Radiant Imaging, Spectra-Physics, Newport and Melles Griot. Web: www.labsphere.com.* DAVID LEIGHTY *is the Group Acquisition Executive for Halma in North America. Email: david.leighty@halma.com. Tel: +1 732 244-1858.*

management and rapidly expanding markets. The acquisition brought together the companies' technical expertise, and meant that rather than having two teams competing to develop and sell similar systems, the single team can now more quickly develop new products and get them to market.

Also, most of the open staff positions that Labsphere was looking to fill as part of its growth plans were filled by SphereOptics personnel, many of them Labsphere veterans.

One product arising from the merger is Labsphere's Thermal/Optical/Electrical LED Measurement System (TOCS). At the time of the merger, both companies were pursuing development of a TOCS system, to enable measurement of optical properties as a function of temperature and operating current using a single instrument. Labsphere's input enabled SphereOptics to finalize the product they had in progress with a sphere design that met all requirements for compliance with IESNA LM-79 (Fig. 2).

FIG. 2. Labsphere's Thermal/Optical/Electrical LED Measurement System (TOCS) (see www.ledsmagazine.com/press/25881).

New opportunities for Halma

With the successful integration of SphereOptics into Labsphere, and the acquisitions of Fiberguide and the US assets of Oerlikon Optics completed in the prior year, Halma has turned its attention to new opportunities. After announcing record results in June, the company has earmarked $150 million for acquisitions of complementary technology companies and continues to look for prospects among photonics businesses.

Companies in LED technology in particular remain a strong area of interest for Halma. Part of the company's acquisition strategy is to pursue industries and products that are both good for the environment and have strong and enduring market drivers. Green-energy technology like LEDs is expected to exhibit growth at a level significantly above the general economy for several years.

While the LED industry is attractive, it is not the manufacture of standard LEDs that appeals to the Halma business model, but the niche markets that either serve the LED industry or produce LEDs that serve specialty markets.

In the first category would be the instrumentation used to test LED performance–either for on-line process measurement or for laboratory testing of LEDs for development and qualification. This could include the test of individual LED lamps or LED displays. Labsphere's products fall into this realm, with their integrating-sphere products and diffuse-reflectance standards serving a large portion of this market. Meanwhile, spectrometers from Ocean Optics are used by OEMs in complex LED sorting systems, and its handheld Jaz model provides spectroradiometric analysis of LEDs, lamps, flat-panel displays and other radiant sources.

The other segment that is of interest would be small manufacturers that produce LEDs for specialty markets. One such market is the emerging UV-LED sector. As a maker of UV water-treatment systems, Halma has a special interest in UV emitters. LEDs that emit UV light at intensities sufficient for commercial use could one day be used in these systems, and may also have applications in Ocean Optics' spectrometers. Halma is also tracking the development of both broad- and narrow-spectrum LEDs for scientific and medical use.

The key to Halma's success is that it acquires a company with the specific aim of growing and developing the business. A good fit with existing sectors and divisions is critical. When Halma evaluates companies for acquisition, it looks for established manufacturing businesses with markets, products, culture and values similar to those of its other group companies. The other essential ingredient is that the target company should offer an enduring competitive advantage in the form of intellectual property: patents, licenses, certifications, specialized manufacturing expertise, or exclusive application-specific knowledge.

Of course, sound financial results and a demonstrated history of growth are also important considerations. Halma is not a turnaround acquirer. It buys successful companies with strong management teams and gives them the resources to grow even more, while continuing to operate with a great deal of autonomy. While company sizes vary greatly, Halma considers a company with $20-25 million in sales to be an ideal size for acquisition, with return on sales and annual growth rates in excess of 10%.

Whenever possible, acquired companies retain their original location, brands and management teams. Halma's decentralized operational structure allows its subsidiaries to function as independent entities while reaping the benefits that come from being part of a large multi-national group. Finally, Halma strongly believes that capital investment unlocks new growth potential for its companies, so it provides the capital required by its subsidiaries to increase capacity and capabilities and drive future growth.

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Thermal protection in LED driver circuits boosts reliability

Despite an efficiency advantage over other light sources, LEDs can still suffer reliability issues if all parts of the lighting system, including the driver, aren't properly protected from over-temperature situations, says **STEVE ROBERTS**.

LEDs are typically around three times as efficient as traditional forms of incandescent lighting and yet they will still fail prematurely if not bolted onto a bulky heat sink. It seems counter intuitive to have a more efficient solid state light that needs more heat-sinking than an inefficient traditional light. Let's consider an example of two floodlights: one using a traditional linear halogen bulb and the other an LED array, to understand the thermal issues involved. We will then discuss how to enhance the LED driver circuit to protect both the driver and the LED from thermally-related premature failure, as a robust thermal system design must account for all elements of the lighting system including the driver.

Both floodlights (Fig. 1) have the same performance in that they both have a radiant power of 5W. Note that watts are the radiometric units of radiant flux while the more commonly given specification of lumens are photometric units of luminous flux. The relationship between watts and lumens is not simple and beyond the scope of this discussion. The point here is that both floodlights look equally bright to the human eye and have roughly similar visible light spectrums.

However, the halogen consumes 150W of electrical power while the LED needs only 55W. The power equations are as follows:

Halogen:

- 5W as visible light (3% of power consumption)
- 125W as radiated infrared (83% of power consumption)
- 20W as conducted heat to the housing (14% of power consumption)

LED:

- 5W as visible light (9% of power consumption)
- 45W as conducted heat to the housing (82% of power consumption)
- 5W lost as heat in the AC/DC LED driver (9% of power consumption).

Thermal environment

Although LEDs are three times more efficient at converting electrical energy into visible light, they generate more than double the conducted heat than an equivalent halogen source. This is why they run so hot if the heat-sinking is not adequate.

On top of this increased conducted heat load, LEDs are more sensitive to over-temperature because they are semiconductor devices with limited maximum operating temperature:

Halogen: Typical lamp temperature = 200°C, typical housing temperature = 50°C

LED: Maximum junction temperature = 115°C, typical housing temperature = 65°C

It is important not to allow the LED to overheat for several reasons. The first obvious effect is the widely-accepted reduction in light output that is attributable to a rise in temperature – impacted both by the ambient temperature and how well the thermal design cools the LEDs.

Secondly, LEDs have a negative temperature coefficient. In other words, with increasing temperature, the diode forward voltage reduces. The coefficient is typically between -3mV/K and -6mV/K, so a typical LED that has a forward voltage of 3.3V at 25°C may have a forward voltage of only 3.0V at 75°C. If the LED power supply cannot cope with the reduction in the total string voltage and still correctly regulate the diode current, the LED will be overdriven and overheat, thus further reducing the forward voltage leading to thermal runaway. The risk of thermal runaway is especially prevalent with low cost LED lamps that use a simple resistor to

FIG. 1. Comparison of two floodlights: one using halogen (top) and one using an LED light source (bottom).

STEVE ROBERTS *is the Technical Manager Europe for Recom Power.*

regulate the LED current. In such a case, the combination of supply voltage tolerance, forward voltage manufacturing tolerances and temperature coefficient can suddenly tip the balance between normal operation and self destruction.

If the LED lamp design is robust enough such that the short term effects of overheating the LED such as the reduced light output and the risk of thermal runaway are negligible, the longer term effects of an elevated operating temperature are nevertheless serious.

Failure mechanisms

There are several mechanisms that can cause a sharp reduction in lifetime with increased operating temperature. Some of the mechanisms that have been identified are chemical deterioration within the LED that occurs at elevated temperatures (e.g. accelerated aging due to thermal stress), humidity ingress and oxidization that occurs because the encapsulation seal is no longer hermetic (e.g. epoxy degradation, contact corrosion or boundary delamination effects) and accelerated semiconductor failures due to mechanisms such as dislocation growth within the silicon, electromigration leading to hot spots in the junction or metal diffusion within the electrical contacts which eventually lead to contact failure.

LED manufacturers spend a lot of time perfecting their manufacturing processes to try and reduce the effect of these various failure modes. Typical LED failure rates escalate gradually with a rise in temperature. But depending on how well a manufacturing process is optimized, that failure rate can have a far greater slope and even a sudden significant inflection point with failures in a broad population of components. However, all LEDs have one thing in common: high operating temperatures reduce the LED lifetime significantly.

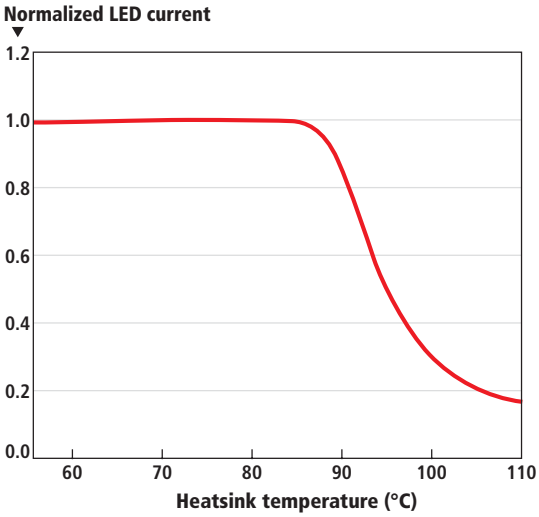

FIG. 3. Current vs. temp output from the example circuit shown in Fig. 2.

The single most likely cause of LED failure remains mechanical stress, however. When an LED heats up to its operating temperature, the encapsulation softens. This allows the electrical connections and any bonding wires to move slightly. When the LED cools down, the epoxy hardens again and this places a mechanical stress on the bond wires which eventually leads to connection failure. There are now LEDs on the market that are fabricated without bond wires specifically to remove this cause of failure.

However, a similar process occurs in the solder connections between the LED and the support PCB, where repeated heating and cooling cycles create fissures that propagate through the solder joint until the electrical connection eventually fails. Thus the most common form of LED failure is an open circuit. The best way to enjoy a long life from an LED is to keep the difference between the room and operating temperatures low or never switch it off.

Although power LEDs are more efficient than many traditional forms of lighting, their power is still limited. This means it is tempting to run the LED as brightly as possible to get the maximum amount of light out of it. We have seen that this can be a dangerous strategy that can lead to early LED failure if care is not taken to keep the LED running cool. There have been several cases where a designer has created a wonderfully elegant LED housing only to find that the heat-sinking is not sufficient or the air flow too restricted. Even a well-designed LED fitting can still fail in use.

The manufacturer of an LED light fitting has no control over how and where the lamp is installed. Problems can occur if there is insufficient flow of air (e.g. the fitting is a recessed lamp fitted into a suspended ceiling which has then been backfilled with insulating rockwool) or if the ambient temperature is excessive (e.g. the LED fittings are arranged vertically on a wall so that the topmost lamp is warmed by all the other lamps below it). In such cases the LED can still overheat and fail.

A solution to this problem is to add thermal protection to the LED driver circuit. If the LED temperature rises too high for whatever reason, the LED current is reduced to reduce the power dissipation within the LED and keep the temperature below a designated maximum. One of the simplest ways to add thermal protection is to use a positive temperature coefficient thermistor in the LED driver circuit.

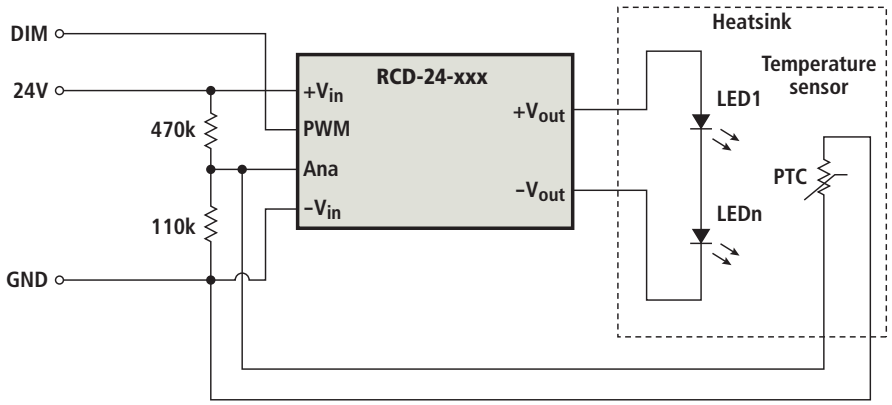

FIG. 2. Example of over-temperature protection using a PTC thermistor.

Thermistor protection circuit

Fig. 2 shows an example using the Recom RCD series LED driver. As the temperature rises above a certain threshold, the

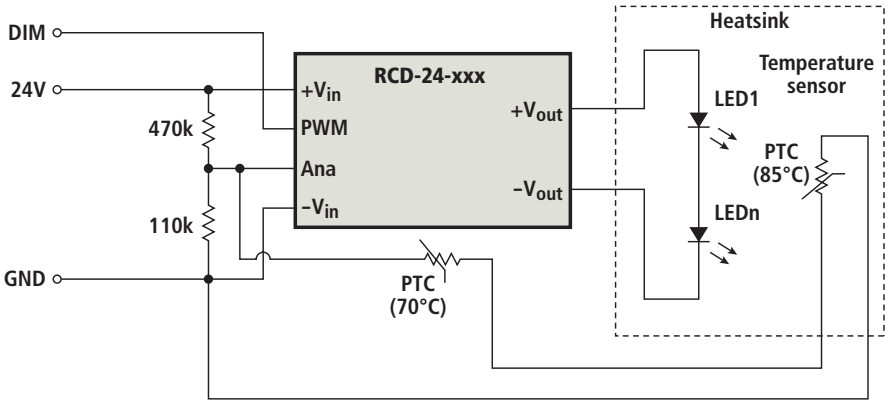

FIG. 4. Using two thermistors to protect both the LED and driver from over-temperature.

resistance of the PTC thermistor increases sharply and causes the LED drive current to be rapidly reduced (see Fig. 3). A nice feature of the RCD driver is that it has two independent dimming inputs, so the LED can still be dimmed normally using the PWM input, while the over-temperature protection uses the separate analogue dimming input to watch over the LED temperature.

By choosing a suitable thermistor and resistor network, the thermal derating point can be made at any chosen temperature. The circuit also gradually dims the LED as it comes close to its maximum operating temperature so that the reduction in light output is not so obvious at first. This is a more pleasing solution than other brute force solutions that use a thermal limit switch that simply cuts the current to the LED if it overheats until it cools down again. It is also often better to have some light output if the LED overheats than to switch the LED off completely and lose all of the illumination.

The added complication of adding just three resistors to the driver circuit will not noticeably reduce the overall system reliability nor add much to the overall cost but the lifetime of the LED fitting will be substantially increased and the down-time and maintenance costs for the light fitting will be greatly reduced.

Finally, it must be said that at elevated operating temperatures the driver reliability will also be reduced. Ideally, the driver should be mounted separately from the LED module so that it is always operating at room temperature, but many lighting designers prefer an all-in-one solution for aesthetic reasons. Many even go so far as to mount the driver directly onto the heat sink or next to the hot LEDs on the circuit board – the worse place of all to position the driver.

Recom RCD drivers include an internal over-temperature protection circuit that will switch them off if they get too hot and they are also designed for high reliability, both at room temperature and at high ambient operating temperatures (for example, the MTBF reduces from 600,000 hours at 25°C to a still very respectable 500,000 hours at 71°C). But if the driver and the LED must be mounted closely together in one unit, then the thermal derating circuit shown above will also extend the lifetime of the driver.

The reduced LED current at high operating temperatures will also reduce the internal heat dissipation within the driver and help it to run cooler. It is, of course, possible to add a second PTC thermistor in series with the LED thermistor so that both the LED temperature and the driver temperature can be monitored with the same circuit (Fig 4). Two different thermistors can be chosen to match the maximum operating temperatures of the driver and LED.

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System compatibility testing improves reliability of LED lighting devices and systems

In the second article in his series on compatibility and reliability, **PHILIP KEEBLER** explains how the concept of system compatibility was developed and how it applies to today's electronic lighting products.

Providing a solid-state lighting (SSL) product to a utility or customer that is reliable and compatible with the utility power system and customer's electrical environment saves money—there's no doubt about it. With the amount of capital required to develop and market advanced lighting products like SSL devices, manufacturers simply cannot afford to spend money on cleaning up utility and customer problems caused by poor and failed performance. Stakeholders in the lighting industry are learning that the performance of an electronic lighting product is not just about efficiency and energy savings. Total product performance must be addressed by manufacturers if end users are to trust and invest in higher-performance lighting products. Total performance must include efficiency and energy savings combined with reliability and compatibility with a central focus on providing higher quality of light and color.

This second article in our series (see Links) defines a relatively new concept – system compatibility – as applied to electronic lighting. It looks at why the concept was developed, and how it applies to today's lighting products.

Definition of system compatibility

System compatibility is defined as the ability of a device, equipment or system – generally a load – to function satisfactorily with respect to its power-supply electrical environment without introducing intolerable electrical disturbances to anything in that environment. This definition applies equally to both the utility power system and the electrical environment inside the customer's facility (see Fig. 1) in both directions i.e. the electronic lighting product must not exhibit poor performance or fail prematurely when subjected to common everyday electrical disturbances in the customer's environment whether the disturbance originated from the utility power system or the electrical system in the customer's environment. Similarly, the electronic lighting product must not cause a performance problem with the customer's electrical environment or the utility power system.

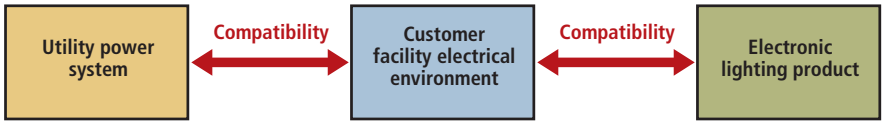

FIG. 1. System compatibility is a two-way street.

This two-way approach to providing compatibility also ensures that electronic products like SSL products can co-exist in the same electrical environment where other electronic products are installed without problem. For example, a minor voltage sag that occurs everyday at 2:04 pm when the customer next door turns on a piece of industrial equipment must not cause electronic lighting products in the adjacent facility to malfunction or fail prematurely. On the other hand, all of the electronic lighting products installed in a customer facility must not cause a harmonic current problem or voltage distortion problem when combined with the non-linear nature of the other electronic loads in the facility that can cause overheating of transformers or power conductors in the customer's facility. Similarly, harmonic currents from lighting products installed in several customer facilities must not combine in a negative way when also combined with other electronic loads to cause a high level of voltage distortion at the point-of-common-coupling (PCC) – the point where the service entrances of facilities come together on the utility power system.

With modern lighting products being all-electronic, utilizing electronic power supplies that produce high-frequency radiated and conducted emissions, electronic lighting products must not cause electromagnetic interference (EMI) problems with loads in the same facility or in the facility next door. Hundreds of other compatibility problems have occurred in the field that could have been avoided if the products had undergone system compatibility testing at EPRI.

Why was the concept developed?

Before discussing why the system compatibility concept was developed, it is necessary to take a look at three basic areas. These areas are important when characterizing (i.e. testing) end-use loads such as LED lighting devices and systems. At the beginning of

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the power system are generators. Generators are located in power plants which inject power into the utility transmission system. The transmission system delivers the power to the utility distribution system where it is then delivered to the customers' revenue (or electric) meter. Across the power system, there are three basic important criteria regarding waveforms of the voltage and current, namely the shape, the amplitude and the frequency of the waveform.

Each of these areas – generation, transmission, and distribution – is associated with a level of exposure to utility-power-system events and acts of nature e.g. thunderstorms. Power-system and natural events will (and always will) cause electrical disturbances to propagate down the system and into customer facilities. The operation of today's non-linear loads and the customer's electrical system also cause numerous disturbances to occur that impact the operation and performance of electronic lighting products. Advanced lighting technologies like SSL lamps and fixtures are by no means spared from these problems, as we will see in the following discussion.

Linear and non-linear end-use loads

In the early days of the power system, end-use loads were either resistive or inductive with few capacitive loads. Resistive loads were made up of incandescent lamps and heater elements. Inductive loads were made up of small to large motors in all customer segments: residential, commercial and industrial. End-use loads – such as the televisions and stereos and some other household appliances your grandmother used to have – used analog power supplies to drive analog circuits and banks of inefficient vacuum tubes used for amplifiers and other circuits necessary to produce video and audio broadcasts. These loads were mostly inductive and partially capacitive. The inductive nature of these loads originated from the large, bulky and heavy transformers used on the front end of these power supplies that would step-down household voltage (i.e. 120 volts) to a smaller AC voltage (e.g. 36 volts) before it could be applied to a tube-based rectifier. Once rectified the voltage was held relatively constant by a voltage regulator so the voltage would not change when the load changed, and it could be applied to the circuits that needed it.

The nature of the loads was such that a smooth sine wave of current was drawn from the electrical system in the customer's facility when the appliance or load was turned on. The currents drawn by the loads in a facility are then passed on to the utility power system through the service entrance. This waveform "smoothness" resulted in a current that was essentially the same shape as the voltage i.e. a sine wave. Because of the similar shape between the voltage and current waveforms, the term "linear load" was coined. Utilities were happy with the fact that the current looked a lot like the voltage. Thus, the majority of early end-use loads were linear loads, and did not cause harmonic problems in customer facility and utility power systems.

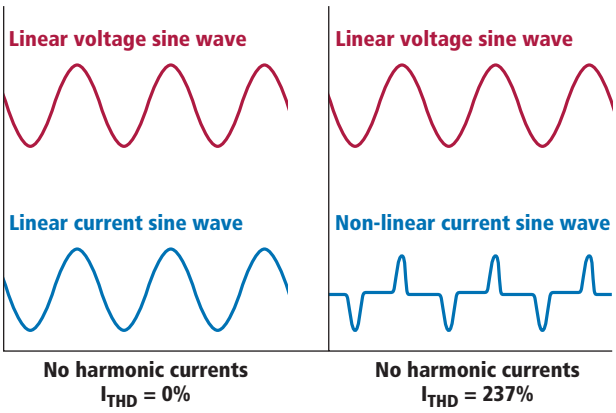

FIG. 2. Waveshape of input line current for (left) linear load and (right) non-linear load.

After the advent of diodes and transistors, end-use loads began to slowly change in how they were designed. The commercial availability of diodes with higher operating voltage and current characteristics allowed the power supply designer to eliminate the need for a stepped-down voltage, and thus eliminate the need for a large step-down transformer. The development of transistors that could handle larger amounts of power and handle larger operating voltages gave rise to new power-supply designs. Not only did the design of power supplies began to change but also their characteristics of the input current they required to operate also began to change.

Unlike linear loads, which drew a smooth sine wave of current, power supplies began to draw current only near the peak of the voltage sine wave. Fig. 2 illustrates the difference in current drawn by linear and non-linear loads. The waveshape of the current drawn by power supplies that used diodes in the bridge rectifier instead of tubes, as well as transistors instead of voltage regulators, began to get more non-linear as power supplies continued to advance.

SMPSs and power factor

With advances in power electronics and microelectronics, power supplies continued to advance. A new type of power supply, called a switch-mode power supply (SMPS), emerged and began to replace analog power supplies. Some of the primary advantages of using SMPSs include higher efficiencies, lighter weight, and consumption of less space on a printed circuit board.

The utility power system is not designed to support high penetrations of non-linear loads with high harmonic currents and poor power factor. High harmonic current levels cause utility transformers to overheat, while unacceptable voltage distortion influences the quality of the line voltage. High harmonic current levels can also cause transformers inside customer facilities to overheat. Electrical systems inside customer facilities typically include a dry-type transformer specifically for reducing facility voltage to a voltage suitable for lighting types (usually 277 or 120 volts). In facilities with three-phase power systems, harmonics currents on each phase result in additive high currents on neutral conductors, many of which are not rated for these currents.

Today's modern SMPSs utilize an additional circuit at the power supply input. This circuit is called an active power-factor correction (APFC) circuit. The job of the APFC circuit is to remove the non-linearity in the AC input current drawn by the end-use load. This is accomplished by "adding in" the miss-

ing part of the sine wave of current. Adding in the missing part of the current waveform removes the harmonic distortion from the sine wave of current. Removal of the distorted current increases the power factor associated with waveform distortion. The APFC circuit also shifts the current waveform in time so that the waveform is lined up (or synchronized) with the voltage sine wave. This synchronization provides a near-unity power factor called displacement power factor. Combination of the two power factors results in the true power factor.

Many of today's electronic lighting products use APFC circuits in ballast and driver design to remove harmonic current distortion and correct for lower power factor. Correcting for high harmonic current requires energy dissipation within the ballast or driver which impacts the overall efficiency of the lighting device. Some manufacturers think that the lower the harmonic current, the better. System compatibility testing at EPRI fully characterizes the improvement in harmonic current distortion and true power factor. Measurement of total harmonic current distortion and true power factor are carried out under various input voltage conditions and operating modes for the electronic lighting product. As a part of EPRI's compatibility concept, guidance is provided to manufacturers regarding how much correction is really needed. In most designs, the amount of correction can be adjusted at the EPRI Lighting Lab during the compatibility testing as a part of manufacturer guidance.

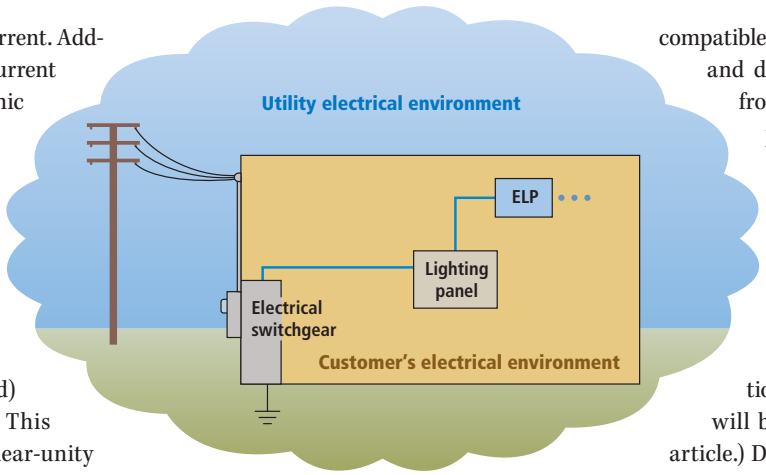

FIG. 3. The total electrical environment for electronic lighting products (ELP).

Increased susceptibility to disturbances

Migration from analog power supplies to SMPSs introduced some serious concerns in ensuring that end-use loads including electronic lighting products were reliable, compatible with the public power system, and did not fail prematurely. The front end of an analog power supply is essentially the primary of the step-down transformer. The use of the transformer provided inherent inductive protection against damage to the power supply caused by electrical disturbances. (The classification and definition of all electrical disturbances will be discussed in an upcoming article.) Destructive voltage waveforms such as voltage surges and voltage transients, which are events characteristic of the common everyday electrical environment, incident upon an analog power supply will not likely cause permanent damage to an analog power supply unless the surge or transient is very high in voltage. However, the same voltage surges and transients that pose essentially no threat to analog power supplies will likely cause permanent damage and failure to SMPSs.

Electronic lighting products with APFC circuitry are even more susceptible to permanent damage and failure from destructive electrical disturbances than products without APFC circuitry. APFC circuits provide several benefits to power-supply circuits used in electronic lighting devices.

Aside from reduced harmonic line currents and improved power factor, benefits include providing a wide range for universal voltage (e.g. 120 to 277 volts) input while holding the DC bus voltage constant as the line voltage and lamp current vary.

APFC circuits are used in all electronic fluorescent ballasts designed to drive linear (tubular) lamps and plug-in style CFLs. Most LED driver circuits also use APFC circuits as well. Some LED driver circuits do not use APFC circuits and will have high harmonic current distortion and poor power factor at the line input. High harmonic current levels in any electronic lighting product may or may not cause problems with the facility electrical system depending upon product wattage and how many products are installed in a facility, among other factors. Low-wattage products which are lightening up on the amount of correction may indeed cause a problem in facility electrical systems, depending on how many products are used in a single system.

All electronic lighting products are susceptible to malfunction and damage from electrical disturbances. In the early days, electronic lighting products used passive power-factor correction (PPFC), because integrated controls for APFC circuits were not yet available. PPFC designs use a large inductor tuned with a capacitor to provide an LC resonant circuit typically tuned to the frequency of the harmonic with the largest harmonic current. Electronic fluorescent ballasts for T8 applications were the first series of lighting products to use PPFC. This inductor in the front end of the ballast circuit also provided some protection for the ballast against transient and surge voltages.

Electronic lighting products that use APFC circuits in the front end of their designs are significantly more susceptible to malfunction and damage from electrical disturbances than products that use PPFC circuits. APFC circuits contain at least one integrated-circuit chip to provide for sensing of the non-linear current drawn by the ballast or driver and for determining how much correction is needed to reshape the current. In addition, APFC lighting products contain a main power transistor device that acts as a switch to operate the correction circuit. This transistor, along with other semiconductor devices such as diodes, are used for signal shaping and for rectification of large currents associated with APFC operation. The presence of these components also adds to increased susceptibility of the lighting product. When a transient or surge damages one of these sensitive components, the APFC circuit will fail resulting in a likely shorting of the APFC power transistor. This is the primary reason that electronic lighting products with APFC circuits should be protected from these disturbances. Protection is typically provided through the use of one or more surge protection devices (SPDs). Testing at EPRI determines several performance factors with respect to the use of SPDs.

EPRI research has shown that some types of APFC circuits will go unstable when the ballast or driver is subjected to certain types of electrical disturbances that contain specific harmonic frequencies in the voltage. This voltage distortion results from operating end-use loads with harmonic content. EPRI testing can determine if a specific electronic lighting product has an unknown, potentially-destructive sensitivity to distorted voltages.

LINKS

Part 1: Compatibility and reliability are key factors in the design of LED lighting devices and systems LEDs Magazine Sept/Oct 2010 p.69: www.ledsmagazine.com/features/7/9/4

Part 3: What does compatibility mean for today's electronic lighting products, particularly LED devices and systems? To be published on LEDs Magazine website, November 2010 www.ledsmagazine.com/features/7/11/1

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last word

7. Attractive exit scenarios in 2-5 years: VC investors eventually need to get their money back (and ideally a nice return), and to do this, one typically has to sell the company to a much bigger company. The current lighting market has a number of large players that have a track record of being acquisitive, adding bolt-on acquisitions to fill their product pipeline and distribution channel. If history is a guide, the LED revolution should bring about a number of mergers and acquisitions within the lighting industry over the next few years as new LED technologies secure market share.

The confluence of the aforementioned elements has set the stage for an accelerated adoption of LED lighting technology. I am encouraged by this, because LED lighting is an excellent step we can take on the long road of becoming a clean-energy/clean-tech society, and should likely be rather profitable for some VC investors and LED entrepreneurs. While I am a big proponent of long-term clean-energy solutions like wind and solar power, we need some short-term wins to satisfy society's short-term gratification and to sustain the momentum to drive the clean-tech revolution forward. LED lighting offers us a highly visible, readily-available technology, with benefits all Americans can understand and it couldn't be much easier ... we all can do our part to help save the planet with the flick of a switch.

last word

Seven drivers for outdoor LEDs

Seven market forces are setting the stage for accelerated adoption of outdoor LED lighting, says **JEFF BOCAN** of venture-capital firm **BERINGEA LLC**.

My fellow readers of *LEDs Magazine* will be fully aware of the LED revolution for outdoor lighting. However, for industry outsiders and the general public, the recent and rather sudden emergence of LED-based lighting is a curious and welcome development. The venture-capital (VC) community in particular is making its awareness and interest known in an aggressive and impactful way. Over the last two years, VCs (my firm included) have stroked checks for a couple of hundred millions of dollars into many LED-lighting related companies. Funding has ranged from new LED technologies to light-engine manufacturers and control-system technologies amongst others in 2010 alone.

As a VC who has spent recent years analyzing and subsequently investing into the outdoor LED lighting sector, I wanted to share my enthusiasm and the investment logic for why many VCs believe this market is set to explode. The outdoor LED market is rather non-existent at this point in time, but over the past two years there has been significant technological advance, cost reductions and increased market awareness of LED lighting, positioning the market for explosive growth. The forces of technological progress, innovation and buyer motivation are on the outdoor lighting industry's horizon, and the winds of change are in the air.

In my view, the following seven forces are driving the outdoor LED lighting revolution and making the LED marketplace particularly attractive to investors:

1. LED technology/product quality: LED lamps are finally good enough to replace existing lamps (in terms of photometrics/light output in the desired area). However, not all LED lamps are equal. A lot of cheap Chinese-made LED products are flooding the market (and some bad American-made products too) which will most certainly leave buyers disappointed – like with anything, you get what you pay for. My fear is that potential spectacular product failures of inferior (but cheap) LED product will poison the market enthusiasm for LED technology. Hopefully, the market will quickly learn that LED luminaires are not a commodity.

2. Cost-competitive/strong return on investment (ROI) metrics: LED lamp costs have come down to a level that – when factoring in energy savings, longer product life and especially reduced maintenance – offers a compelling investment for municipalities, corporations, utilities and institutions.

3. Stimulus funding and "green" subsidies: The famed "Stimulus Program" provided hundreds of millions of dollars to cities for energy-efficiency programs and this cash is just now hitting city coffers. Utilities are offering rebates to customers for LED purchases as well. These subsidies make LED purchases more attractive and are helping the industry get down the cost curve with accelerated scale.

4. Municipalities are moving up the learning curve: LED lighting products are highly technical and there is a substantial difference in product quality between cheap knock-offs and market-leading products. Over the past two years, many municipal and utility purchasing departments have been educating themselves on LED technology (e.g. the importance of thermal management for LEDs) and conducting evaluations of various LED lamps. The DOE's Municipal Consortium has been particularly helpful, and this market-wide educational effort will enable the majority of the market to rapidly follow early-adopter cities such as Ann Arbor and Los Angeles. In short, the market should move pretty quickly, even taking into account that most of the buyers are governments and utilities – neither entity is oft mentioned in a sentence with the adverb "quickly," but the planets seem aligned.

5. Public embrace of "green" technology and concern about reducing carbon footprint: The public has raised its expectations for "green" behavior and action from cities, companies and institutions. A synchronized push/pull dynamic is developing and accelerating the market, whereby citizens are "pushing" for greener institutions, while those institutions are being "pulled" by stimulus funding, rebates and aggressive LED lamp salespeople!

6. Incumbent politicians scoring political points: The installation of LED lights is a quick and highly visible action for local politicians to demonstrate that they are proactive in "greening" their communities. In a US election year poised to be dangerous for incumbents, outdoor LED lighting is a tangible benefit a politician could point to and take credit.

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