Voices for SSL Efficiency 2009

Solid-State Lighting Market Introduction Workshop

July 13–15, 2009 • Chicago, Illinois

U.S. DEPARTMENT OF ENERGY

MEEA Midwest Energy Efficiency Alliance

Report

Solid-State Lighting Research and Development Portfolio
Building Technologies Program
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

November 2009

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ACKNOWLEDGEMENTS

The Department of Energy acknowledges and thanks all the participants for their valuable input and guidance provided during the 2009 DOE SSL Market Introduction Workshop. The Department also thanks all the direct contributors and especially the following individuals:

Michael Barber, City of Anchorage, Alaska
Derry Berrigan, Derry Berrigan Lighting Design
Dan Blitzer, The Practical Lighting Workshop
Steven Briggs, GE Lumination
Chad Bulman, Midwest Energy Efficiency Alliance
Martha Carney, Outsourced Innovation
Shana Cockerham, D&R International
Kelly Cota, National Grid
Robert Gibson, National Rural Electric Cooperative Association
Kelly Gordon, Pacific Northwest National Laboratory
Chris Granda, Vermont Energy Investment Corporation
Mark Hamann, ComEd
Bill Hamilton, The Home Depot
Tom Harold, Grainger
Mark Hodapp, Philips Lumileds Lighting Company
Wendy Jaehn, Midwest Energy Efficiency Alliance
Richard Karney, U.S. Department of Energy
Bruce Kinzey, Pacific Northwest National Laboratory
Emily Klingensmith, Schuler Shook
Marc Ledbetter, Pacific Northwest National Laboratory
Deanna Matthews, Carnegie Mellon University
Mark McClear, Cree, Inc.
Jeff McCullough, Pacific Northwest National Laboratory
Avraham Mor, Lightswitch Architectural
Eric Richman, Pacific Northwest National Laboratory
Scott Riesebosch, CRS Electronics
Marci Sanders, D&R International
Ron Steen, Xicato
Ruth Taylor, Pacific Northwest National Laboratory
Jason Tuenge, Pacific Northwest National Laboratory
Marsha Turner, International Association of Lighting Designers
Dan Weinheimer, City of San Marcos, California
Scott Wentworth, City of Oakland, California
Liesel Whitney-Schulte, Wisconsin Energy Conservation Corporation
Ralph Williams, Walmart

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This report was prepared for the U.S. Department of Energy and the National Energy Technology Laboratory by Akoya under NETL Order Number: DE-NT0005282.

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1. INTRODUCTION AND OVERVIEW

View of Lake Michigan from the SSL Market Introduction Workshop, July 13-15, 2009

More than 300 lighting industry leaders gathered in Chicago on July 13–15, 2009, for the fourth annual Solid-State Lighting (SSL) Market Introduction Workshop, hosted by the U.S. Department of Energy (DOE) and the Midwest Energy Efficiency Alliance (MEEA). Prompted by the urgent need for reliable information in the face of a rapidly evolving market, the workshop series provides a focal point for government, industry, energy efficiency organizations, utilities, municipalities, designers, specifiers, retailers, distributors, and others to share updates and insights on the successful market introduction of high-quality, energy-efficient SSL solutions.

Section 2 of this report covers the pre-conference tutorials that took place on July 13. DOE SSL Portfolio Manager James Brodrick kicked off the tutorial session with an overview of the workshop's purpose and DOE's various pathways to market. The tutorials that followed provided an introduction to DOE's market-based programs, including CALiPER testing, GATEWAY demonstrations, Quality Advocates, ENERGY STAR® for SSL,* standards development, and design competitions. Additional tutorials provided a solid basis for understanding the market introduction of SSL and laid the groundwork for the panels and presentations that followed on Days 2 and 3.

Section 3 of this report covers the opening of the workshop on July 14. In his welcoming presentation, Brodrick noted the widespread confusion surrounding the rapidly evolving SSL market and underscored the need for reliable information. MEEA's Wendy Jaehn noted the rapidity with which SSL technology is changing and observed that having inferior products in the marketplace could give the whole technology a bad name. Section 4 covers the keynote address, given by Mark McClear of Cree, Inc., who offered a candid evaluation of the current status of the LED lighting revolution.

Section 5 covers a panel discussion on LED product assessment, which ranged in topic from DOE's Quality Advocates program, to ENERGY STAR criteria for SSL, to the importance of reliable technical data, to the issue of color. Section 6 covers a panel discussion on marketing LED lighting products, which presented the twin perspectives of

* On September 29, 2009, DOE and the Environmental Protection Agency (EPA) announced a new Memorandum of Understanding (MOU), detailing roles and responsibilities for ENERGY STAR program management, including SSL. Beginning October 1, DOE transferred full responsibility for management of the ENERGY STAR SSL program to EPA.

a large retailer and a major distributor. Section 7 deals with the issue of life cycle assessment, focusing on the progress to date in the DOE SSL Life Cycle Assessment study. Section 8 covers a panel discussion on strategies and best practices for implementing LED lighting incentive programs, presented by representatives from utilities and energy efficiency organizations. Section 9 covers a panel discussion on outdoor street and area lighting that focused on the firsthand experiences of several municipalities and a major retailer.

Section 10 covers a panel discussion in which a number of lighting designers gave their perspectives on designing with LEDs, and recounted some of their own experiences. Section 11 covers a panel discussion on LED reliability, including defining it, designing for it, and adjusting the manufacturing process to maximize it. Section 12 covers a panel discussion on cost-effectiveness, which looked at the value of SSL's benefits other than energy efficiency and also presented the municipality and utility perspectives.

Section 13, "Next Steps," describes plans and highlights milestones associated with DOE SSL Market Introduction activities since the July workshop. Workshop presentations and materials referenced in this report can be found on the SSL website at www1.eere.energy.gov/buildings/ssl/chicago09_materials.html.

2. PRE-CONFERENCE TUTORIALS AND TOUR

2.1. DOE Market Introduction Activities

James Brodrick, U.S. Department of Energy

Brodrick observed that the rapid development of SSL technology, coupled with a growing number of products on the market, has resulted in a great deal of confusion. He noted that while some SSL products meet manufacturer specifications and outperform conventional technologies, many more do not.

What's needed, he stated, is education and information exchange along the entire lighting industry chain, from researchers to manufacturers to buyers. "There's a ton of information floating around," said Brodrick. "We want to separate the facts from the fiction."

Brodrick outlined the general schedule of the workshop and the topics to be covered. Then he reviewed the various DOE "pathways to market" for SSL, including the program areas covered in the upcoming tutorials, the SSL web site, the SSL technology fact sheet series, the SSL Technical Information Network, and workshops and conferences.

2.2. Tutorials

Day 1 of the Chicago workshop was devoted to tutorials that provided a foundation for understanding the market introduction of SSL and laid the groundwork for the panels and

presentations that would follow on Days 2 and 3. These tutorials introduced DOE's market-based SSL programs, including:

- CALiPER testing, presented by Marc Ledbetter of Pacific Northwest National Laboratory (PNNL)
- GATEWAY demonstrations, presented by Bruce Kinzey of PNNL
- Quality Advocates and the Lighting Facts℠ pledge program, presented by Marci Sanders of D&R International
- ENERGY STAR for SSL, presented by Richard Karney of DOE
- Standards development, presented by Eric Richman of PNNL
- *Lighting for Tomorrow* and *Next Generation Luminaires*™ design competitions, presented by Ruth Taylor of PNNL
- *L Prize*℠ design competition, presented by James Brodrick.

Additional tutorials reviewed appropriate applications for LED lighting (presented by Kelly Gordon of PNNL) and examined the issue of why measuring fixture efficacy provides a more accurate performance measure than source efficacy (presented by Jeff McCullough of PNNL).

2.3. Walking Tour

The tutorials were followed by an optional evening walking tour that provided a firsthand look at several LED installations in downtown Chicago. Sponsored by the Merchandise Mart, the tour began at this 25-story building, the largest LEED-certified commercial building in the world. The Merchandise Mart continually pilots new LED technology products in its office, vendor, and maintenance areas, and Vice President of Engineering Mark Bettin provided a behind-the-scenes tour of areas usually closed to the public.

The first stop on the LED walking tour in downtown Chicago was the 25-story Merchandise Mart, the largest LEED-certified commercial building in the world.

Highlights included an office space where the reception area was lighted by LED downlights, and adjacent conference rooms provided side-by-side comparisons of typical fluorescent overhead lighting and LED lighting. Bettin pointed out the visible difference in each conference room, emphasizing that each room had the same paint color on the walls. In the basement of the building, LED hi-bay fixtures were installed in one area of the loading dock to enable comparison with the existing low pressure sodium fixtures. Bettin noted the increased light levels in the LED-lighted area, despite the fact they were able to eliminate three fixtures on that side.

The next stop was the newly renovated Wit Hotel, where lighting designer Avraham Mor of Lightswitch Architectural guided a tour of the 27-story hotel/condo building. Mor shared that the building owner has two very specific goals for this project: to beat ASHRAE 90.1-2004 and to have an all-LED building. The first goal was met, and the building is 20 percent under code. The second goal was harder to achieve, and Mor found that a mix of lighting solutions was needed. On the tour, he noted that the hotel features 3,500 linear feet of LED cove lighting in the entrance, elevator lobbies, conference rooms, the spa, and other areas. The tour concluded in the rooftop bar, which also features LED lighting, with a reception sponsored by Lightswitch Architectural.

The in-house theatre at the Wit Hotel features LED step lighting – the same product that won a 2008 Next Generation Luminaries *design award.* Photo ©2009 Wayne Cable, SelfMadePhoto.com

3. WELCOME

James Brodrick, U.S. Department of Energy, and Wendy Jaehn, Midwest Energy Efficiency Alliance

Brodrick outlined DOE's SSL program strategy, from core technology research, to product development, to manufacturing, to standards development, to commercialization support. He emphasized DOE's key partnerships with such organizations as the Next Generation Lighting Industry Alliance (NGLIA), the International Association of Lighting Designers (IALD), and the Illuminating Engineering Society of North America (IES) as well as DOE's collaborative efforts with key standards-setting organizations such as the American National Standards Institute (ANSI), the National Electrical Manufacturers Association (NEMA), the National Institute of Standards and Technology (NIST), and Underwriters Laboratories Inc. (UL).

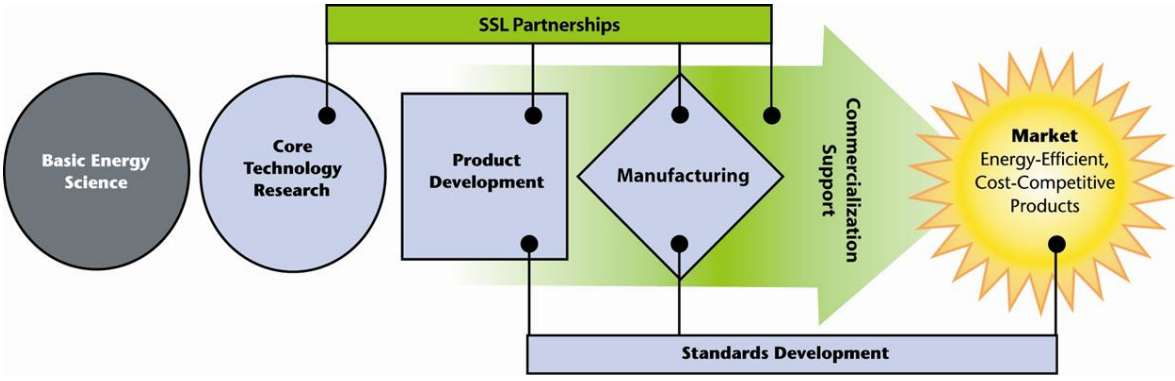

Figure 1: DOE Solid-Sate Lighting Program Strategy

Brodrick reviewed DOE's various pathways to market, including market studies and technical evaluations, the SSL Technical Information Network, CALiPER testing, SSL Quality Advocates, ENERGY STAR® for SSL,* GATEWAY demonstrations, the Retailer Energy Alliance, the *Lighting for Tomorrow* competition, the *Next Generation Luminaires* competition, the *L Prize* competition, and annual workshops and conferences. "Most of these pathways didn't exist two-and-a-half years ago, but were developed based on your feedback," he said.

Wendy Jaehn, MEEA, observed that in a relatively short time, LEDs have progressed from being indicator lights on appliances to a general illumination source with the potential to surpass the efficiency of most other lighting technologies available. She predicted that the flexibility of SSL will change the ways light is integrated into our surroundings.

However, caution should be applied to any technology that's still developing. "Solid-state lighting has introduced an entirely new set of performance metrics, testing procedures, and technical issues, and in the midst of it all the technology is transforming so rapidly that the understanding of SSL we held yesterday may not have relevance today," she said.

Jaehn observed that having inferior SSL products in the marketplace could give the whole technology a bad name. "We really want to see the LED market become competitive," she said, adding that she hoped the workshop would address such questions as how to mold an energy efficiency program to LED technology, what technical information is needed to evaluate an LED product, and what applications are suitable right now for LED technology.

4. KEYNOTE: THE LED LIGHTING REVOLUTION – ARE WE THERE YET?
Mark McClear, Cree, Inc.

McClear's keynote address explored the question of whether LED lighting has truly arrived, in the sense that it saves energy and money and is good for the environment. He concluded that some groups are, indeed, "there," while others aren't, and stressed the importance of education to facilitate the process.

McClear suggested that many manufacturers are "there," noting that major breakthroughs in brightness, efficacy, and color warmth have enabled LEDs to compete with incumbent products. He noted that component manufacturers have also made significant breakthroughs in drivers, optics, and thermals. In addition, McClear made the point that many municipalities, universities, and governments are willing to try new technologies, and are looking closely and objectively at LED lighting technology on college campuses, on roadways, and in government offices, as well as in a number of LED street lighting projects across the country. He also highlighted SSL use in the commercial sphere, in

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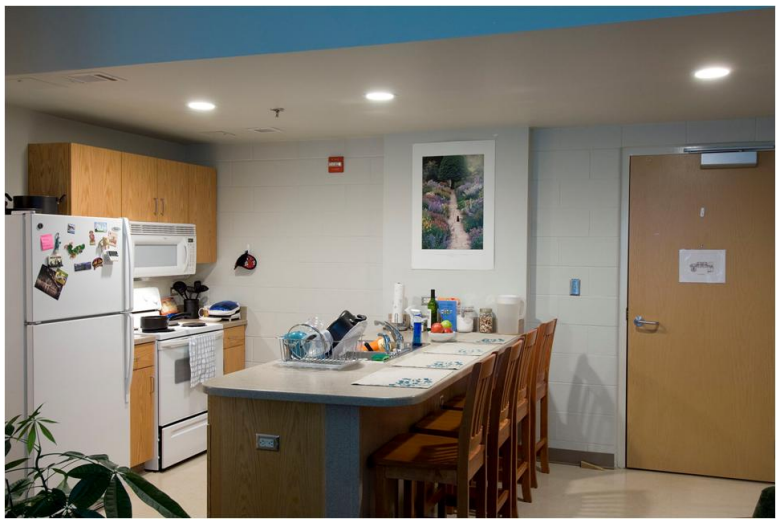
restaurants, hotels, and gas stations, and observed that all these pilots and demonstrations increase volumes and help drive costs down.

McClear stated that consumer SSL bulbs will take a while longer to develop to the point where they can compete with conventional bulbs. The key to this process is a system approach that includes breakthroughs in packaging, phosphors, optics, and thermal components, and that also addresses red spectral content and dimming.



Cree LR6 downlight installation in student housing at North Carolina State University

McClear observed that there's still some work to be done with regards to creating SSL standards. While having the best LED is crucial, it's not sufficient in and of itself, because the other luminaire components are also important. He stated that "it's going to take a while to get the technology improved and the cost down so that it (SSL) makes sense at the consumer level."

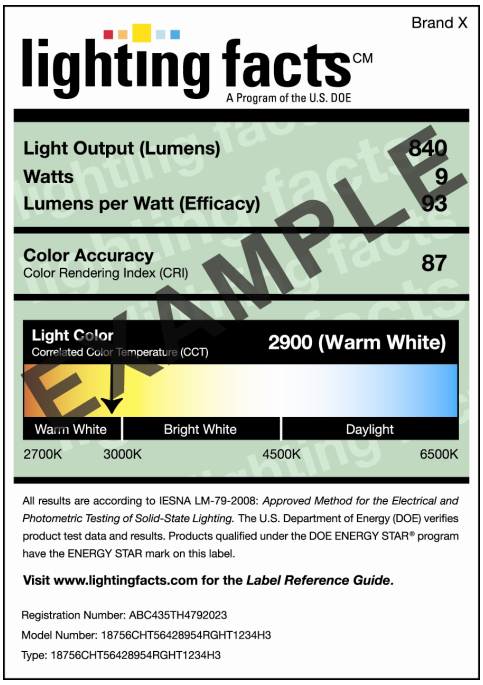
5. PANEL 1: PRODUCT ASSESSMENT

James Brodrick, U.S. Department of Energy (Moderator); Richard Karney, DOE ENERGY STAR program; Scott Riesebosch, CRS Electronics; Ron Steen, Xicato

This session offered practical information, including available tools and guidance to help evaluate and compare the many new LED products emerging on the market. Brodrick kicked it off by noting that SSL has the potential to cut U.S. lighting energy use by one-third by 2030 for a cumulative cost savings of $280 billion, and to yield annual energy savings equivalent to 348 billion kilowatt hours — the greenhouse gas emissions of 47 million cars — as well as to create high-tech jobs.

He observed that LED products are rapidly entering the market, and that while some of them are good, many don't perform as claimed, resulting in confusion that could hamper market acceptance. Brodrick said the goal is to avoid what happened with the market introduction of CFLs. Citing important lessons learned from that experience, he noted that credible information is key to consumer acceptance, and that collaboration reduces confusion. Brodrick also made the point that the focus should be on applications where LEDs can meet or exceed expectations.

He reviewed the ways that DOE can help, including programs that provide education, tools, and unbiased information, such as CALiPER, Quality Advocates, and design competitions. "We want to get good information out there," Brodrick said. He explained how the Quality Advocates program has introduced the Lighting Facts label, which is being used to provide "just the facts" on five aspects of product performance. The number of those pledged as Lighting Facts partners — manufacturers, retailers, distributors, lighting designers, efficiency programs, and utilities partners — is growing, giving buyers a new source for locating LM-79 tested products.



The "Lighting Facts" product label, promoted by SSL Quality Advocates

Brodrick also highlighted a new listing of commercial lighting products deemed specifiable from the *Next Generation Luminaires* competition.

Brodrick was followed by Karney, who stated that the primary goal of DOE's ENERGY STAR program for SSL is to accelerate market adoption of quality SSL products by enabling buyers to distinguish good products from poor products, thus avoiding buyer dissatisfaction. The program works with both consumers and manufacturers.

Karney remarked on the speed with which the ENERGY STAR for SSL program is gaining momentum, noting that as of July 1 there were 127 manufacturing partners and 28 qualified products, with six promotions by energy efficiency programs currently running and another nine planned.

Karney went over the ENERGY STAR for SSL program tools in place to make it easier for lighting manufacturers to participate in the program, which include Web pages, a Partner Resource Guide, a Commercial Cut Sheet, a Program Design Guide, and media outreach and support.

He said priorities for 2009* include developing and launching a third-party testing and verification program; expanding the number of applications eligible for the program; introducing ENERGY STAR criteria for LED-based replacement and outdoor lighting products; and working with partners to ensure consumer adoption.

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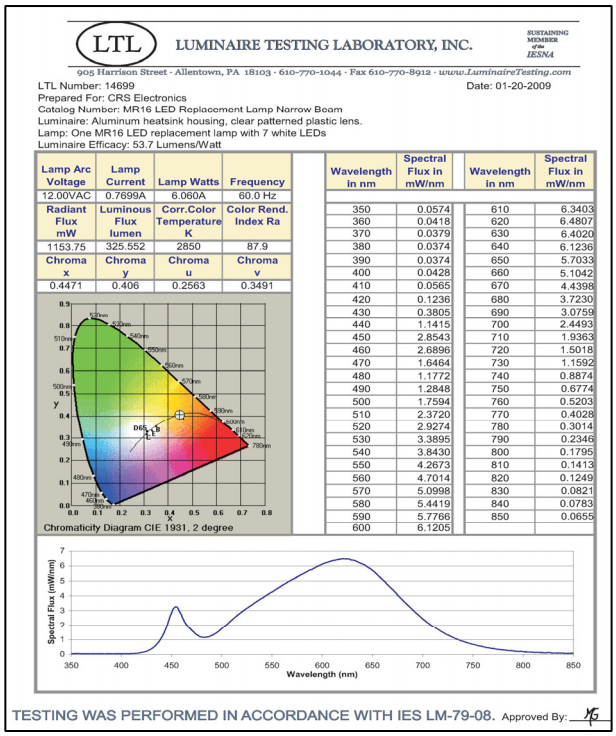
Karney was followed by Riesebosch, who gave a primer on what one needs to know when evaluating LED lighting. Making the point that "all LEDs are not created equal," he noted, among other things, that efficacy ranges from 40 lumens per watt to >100 lumens per watt, and that there is wide variation in lumen depreciation. Riesebosch observed that data sheets are often inaccurate, with specifications often not based on real-world conditions, and that color can shift dramatically over time. He also noted that at present there are about 17,000 suppliers of "LED bulbs" and nearly 200 suppliers of LED streetlights.

Riesebosch made the point that in LED products, the LEDs may not be the weakest link, as there are other components that may wear out sooner, sometimes because they have reduced life expectancies at elevated temperatures. He observed that many of these are inferior, "grey market" components that are used in the manufacture of LED products. Riesebosch also explained that the system efficiency of an LED luminaire is obtained by multiplying four factors with each other: driver efficiency, optical efficiency, thermal efficiency, and LED efficacy. So for example, a luminaire with an LED efficacy of 90 lumens per watt, a driver efficiency of 85 percent, thermal degradation of 8 percent, and a two-component optical system consisting of an 85-percent efficient TIR and a 90-percent efficient reflector, would have a system efficiency of 90 x 0.85 x 0.85 x 0.9 x 0.92 = 53.8 lumens per watt.

Riesebosch also discussed why junction temperature is important, explaining that the LED junction is the area of the chip that actually creates light ("the heart of the LED"), and that under normal operation it gets very hot. He observed that running an LED above its rated maximum junction temperature will decrease its active lifetime and accelerate its lumen maintenance loss, so careful design is crucial. For example, he noted that increasing the junction temperature by 20º C reduces lifetime by two-thirds, which is why it's so important to look at *in situ* junction temperature.

Participants during the first panel Q&A session

Riesebosch stressed that technical details must be included on data-sheets for LED luminaires and fixtures, and that if a manufacturer can't supply technical data, it might mean the product hasn't been tested thoroughly. He advised asking for IES files and LM-79 independent lab test results, even for replacement lamps, and reviewed what an LM-79 report looks like. In the context of managing risk, he also advised looking at the total cost of owner-ship rather than trying to save money just on acquisition costs, which could result in buying inferior products.



LTL LUMINAIRE TESTING LABORATORY, INC.

SUSTAINING MEMBER of the IESNA

905 Harrison Street · Allentown, PA 18103 · 610-770-1044 · Fax 610-770-8912 · www.LuminaireTesting.com

LTL Number: 14699 Date: 01-20-2009

Prepared For: CRS Electronics

Catalog Number: MR16 LED Replacement Lamp Narrow Beam

Luminaire: Aluminum heatsink housing, clear patterned plastic lens.

Lamp: One MR16 LED replacement lamp with 7 white LEDs

Luminaire Efficacy: 53.7 Lumens/Watt

Lamp Arc Voltage	Lamp Current	Lamp Watts	Frequency
12.00VAC	0.7699A	6.060A	60.0 Hz
Radiant Flux mW	**Luminous Flux lumen**	**Corr.Color Temperature K**	**Color Rend. Index Ra**
1153.75	325.552	2850	87.9
Chroma x	**Chroma y**	**Chroma u**	**Chroma v**
0.4471	0.406	0.2563	0.3491

Chromaticity Diagram CIE 1931, 2 degree

Wavelength in nm	Spectral Flux in mW/nm	Wavelength in nm	Spectral Flux in mW/nm
350	0.0574	610	6.3403
360	0.0418	620	6.4807
370	0.0379	630	6.4020
380	0.0374	640	6.1236
390	0.0374	650	5.7033
400	0.0428	660	5.1042
410	0.0565	670	4.4398
420	0.1236	680	3.7230
430	0.3805	690	3.0759
440	1.1415	700	2.4493
450	2.8543	710	1.9363
460	2.6896	720	1.5018
470	1.6464	730	1.1592
480	1.1772	740	0.8874
490	1.2848	750	0.6774
500	1.7594	760	0.5203
510	2.3720	770	0.4028
520	2.9274	780	0.3014
530	3.3895	790	0.2346
540	3.8430	800	0.1795
550	4.2673	810	0.1413
560	4.7014	820	0.1249
570	5.0998	830	0.0821
580	5.4419	840	0.0783
590	5.7766	850	0.0655
600	6.1205		

Spectral Flux (mW/nm)

Wavelength (nm)

TESTING WAS PERFORMED IN ACCORDANCE WITH IES LM-79-08. Approved By:

Figure 2: LM-79 Report

Riesebosch was followed by Steen, who focused on the issue of LED color consistency. Steen explained that because LEDs are so complex, variations in the manufacturing process give rise to color consistency issues in the finished product. He observed that there are existing metrics in place for measuring the color of light, including the CIE diagram, Black Body Curve, and MacAdam ellipses.

Steen went over the strengths and limitations of each of these tools. He provided guidance on how to fine-tune them to better suit the purpose, so that the consumer isn't disappointed. He also emphasized the importance of taking into consideration the specific lighting application, because color consistency requirements can vary from application to application.

Steen cautioned against specifying color based on CCT alone, because this "only gets you in the ballpark; it does not define color." He illustrated this point in dramatic and memorable fashion by showing the audience three pairs of lights, each of which were matched for CCT, but only one of which was close enough that the difference between the color of the two lights was unnoticed by most people.

That pair was measured to be within two MacAdam ellipses (i.e., where the measurement doesn't vary by more than two MacAdam "steps"). Steen explained that the 2-step MacAdam ellipse is most suitable for use in applications where the white LEDs or fixtures are placed side-by-side and are directly visible, or are used to illuminate an achromatic scene. By contrast, a 4-step MacAdam ellipse allowance should probably be confined to applications where the white LEDs or fixtures are not directly visible, or when they're used to illuminate a visually complex, multicolored scene; and a 6-step MacAdam ellipse allowance should have even more restricted use.

But Steen's overarching message was to beware when specifying by CCT, because wide variations exist, and to follow a three-step procedure: select the desired CCT, look at the specific application, and then recommend a 2-step MacAdam range.

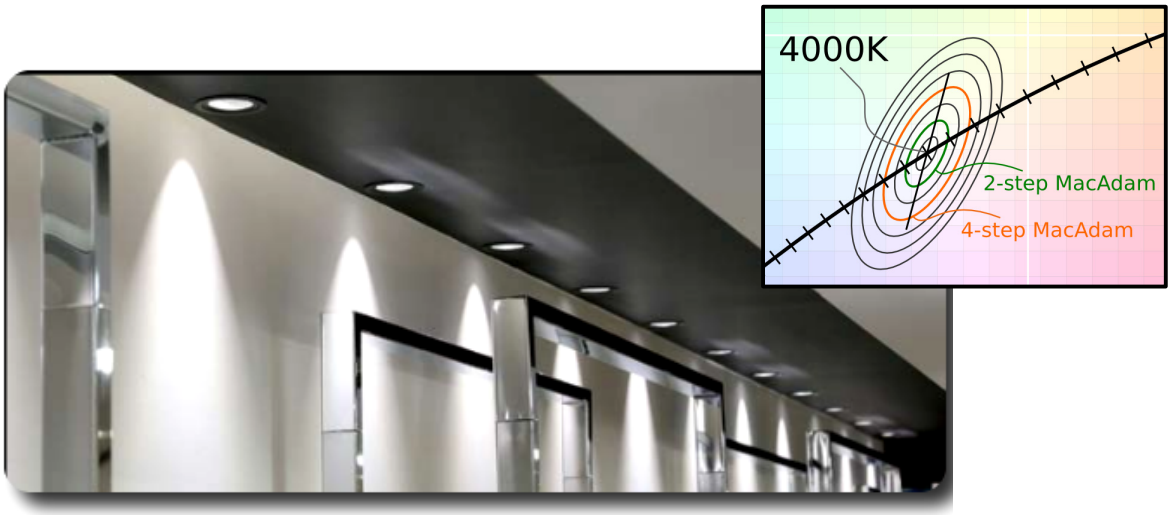


Figure 3: Color Consistency Requirements Depend on Application

6. PANEL 2: MARKETING LED LIGHTING PRODUCTS

Shana Cockerham, D&R International (Moderator); Tom Harold, Grainger; Bill Hamilton, The Home Depot

The panel was moderated by Cockerham, who gave a brief introduction and noted that retailers and distributors play a key role because they're the last group to interact with consumers before the purchasing decision is made.

Grainger was represented on the panel to provide business-to-business perspective as a major distributor of maintenance, repair, and operations supplies, with access to 850,000 products and $6.9 billion in annual sales. Harold noted that Grainger carries more than 7,400 lighting products, with sales of those products accounting for 6 percent of total sales in 2008, and that the company has been an ENERGY STAR partner since 2001. As a result of ENERGY STAR products sold through Grainger, customers saved an estimated 152.4 million kWh in 2008, yielding an estimated savings of $16.9 million on electricity bills. The energy saved was enough to light every household in Washington, D.C., for 115 days, with reduction in carbon emissions equivalent to removing 19,500 cars from the roads.

Harold discussed the lessons his company learned from CFLs, which it began carrying in 1995. There was considerable customer disappointment due to quality of light, delay, flickering, and lack of dimmability. He described current issues with some LED products — poor light output, exaggerated lifetimes, and poor or inconsistent color quality — noting that this need for product standards led Grainger to sign on as a Lighting Facts partner in the fall of 2008.

Harold said the Lighting Facts program makes evaluating potential suppliers a straightforward matter because it provides a consistent set of quality metrics that enable buyers to make sound decisions, which in turn increases customer satisfaction and "ultimately will drive faster market adoption of LED technology in general." He read aloud to the audience the strongly worded letter Grainger sends to its current and potential lighting suppliers, which asks them to take the Lighting Facts pledge to confirm that their products have been tested to the appropriate industry standards.

Home Depot was represented on the panel as the world's largest home-improvement retailer and number-one seller of light bulbs, with $71 billion in annual revenue. Hamilton said LEDs "are coming like a freight train" and will eventually replace incandescent bulbs because of the energy savings. But he noted that consumers' high expectations for SSL need to be brought down to reality and called for improved product quality and consistency, emphasizing that Home Depot won't consider carrying any lighting products that have not been LM-79 tested.

Hamilton said that LED retrofit and LED fixture solutions must coexist, and reviewed the major considerations of each category. He noted that retrofit is the fastest method of LED adoption at the residential level, because of the ease of installation and comparison with conventional bulbs, and that LED replacement lamps do best where CFLs are not a viable option. He also noted the challenges of explaining such matters to customers and called education the key to accelerating the adoption of LED technology.

Hamilton said that The Home Depot is seeing high return rates on LED replacement lamps because many of them are of low-quality, which is hurting the industry. He stated that true replacement by LED lighting products is still cost-prohibitive, and emphasized the importance of the "early adopters" who form the vanguard of those purchasing LED lighting products.

Hamilton emphasized that his company intends to focus on quality and consistency in LED lighting, to avoid customer dissatisfaction and facilitate adoption of the technology. He noted that the greater the adoption rate, the higher the sales volume and the lower the price.

Panel 2 was followed by a lively session of questions and comments from the audience that covered a wide range of topics. For example, lighting designer Avraham Mor noted that some of the better LED lighting products that he specifies to clients are difficult to

Participants during the Panel 2 Q&A session

find, and he asked both panelists how their companies are educating customers about the difference between the good LED products and the bad. Hamilton replied that The Home Depot has information about that on its website and is also in the process of improving the store signage to better educate the customers, as well as working with DOE on finding other ways to do that. Harold said Grainger is taking a similar approach, with the goal of giving customers the right information so that they can make the best buying decisions.

7. DOE SSL LIFE CYCLE ASSESSMENT

Deanna Matthews, Carnegie Mellon University

Matthews presented a snapshot of the progress to date in the DOE SSL Life Cycle Assessment study, which is looking at all the materials and energy resources required for SSL products over their entire life cycle and comparing them with other lighting technologies. The underlying concerns of such a study are that production of LED components is energy-intensive and could outweigh savings during use, and that there might be hazardous materials present that could pose a risk to consumers.

Matthews gave an overview of the project, which focused on a retrofit lamp with an integrated driver, an Edison base, and an LED array of 5-20 packaged LEDs, with current operating specs of 30 lumens per watt, 200-300 lumens, 25K hours, and projected future operating specs of 150 lumens per watt, 600 lumens, 50K hours.

She then reviewed the project's approach and data sources, noting that at the manufacturing level, there is currently limited information on LED materials and lamp processing, while the data on LED processing come from equipment manufacturers and research lab metering, and the data on lamp materials come from larger components and life cycle information databases. Matthews explained that at the use stage, the study uses parametric modeling of lamp operating conditions, and that the end-of-life stage is still in the initial phase of investigation.

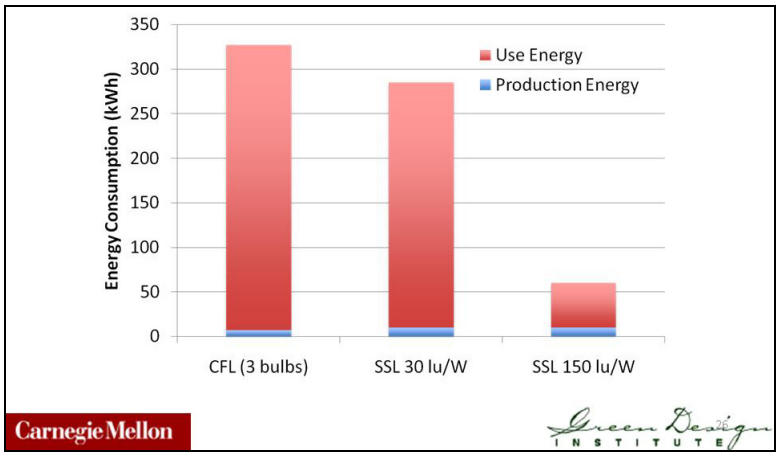


Figure 4: Lighting Life Cycle Energy Consumption Comparison

She concluded that, based on the study results to date, the production energy for LED products appears to be small relative to use energy. Matthews made the points that uncertainties in the manufacturing phase matter as efficacy improves, and that uncertainties in the lamp life matter as LED lifetime improves. She noted that while LED processing is currently a small contributor to overall energy consumption of production, the materials for the lamp, especially the heat sink, are a significant contributor. But she stated that designs are expected to reduce material needs as heat sink designs are optimized to reduce cost, and that there will be opportunities to reduce overall life cycle energy consumption if these materials can be recovered (i.e., if take-back or recycling are systems implemented).

8. PANEL 3: GETTING STARTED

Chad Bulman, Midwest Energy Efficiency Alliance (Moderator); Mark Hamann, ComEd; Kelly Cota, National Grid; Liesel Whitney-Schulte, Wisconsin Energy Conservation Corporation (WECC); Robert Gibson, National Rural Electric Cooperative Association (NRECA) with Martha Carney, Outsourced Innovation

Midwest Energy Efficiency Alliance is a collaborative network advancing energy efficiency, ComEd and National Grid are utilities, WECC administers energy efficiency programs (EEPs), and NRECA is a trade organization representing electric cooperatives. Their representatives were invited to provide insights on lighting incentives and programs, as well as on strategies for implementing them.

The panel commenced with Bulman, who introduced the other panelists. “Broadly speaking, we’re starting to move from niche incentives on products like holiday strands and nightlights more into the realm of general illumination through pilot, outdoor, or commercial LED installations,” he said. “But we’re also starting to see some custom incentives programs coming about, and I think as standards are beginning to develop, we’re even seeing some prescriptive incentives coming to the fore.”

Bulman was followed by Hamann, of ComEd, which provides service to approximately 3.8 million customers across northern Illinois, or 70 percent of the state’s population. Hamann called SSL the “perfect storm for energy efficiency programs” because of the combination of high interest in the technology, the proliferation of poor-quality products, and limited standards and specifications to guide customers — all of which can lead to a negative public perception. “What we’re trying to avoid is a poor customer reaction to a new technology,” he said.

Another challenge for LEDs is high initial cost. In that context Hamann discussed the concept of total resource cost (TRC), a standard used by many utility programs, which is the ratio of net present value of benefits to net present value of costs over the lifetime of the measure, and which ideally should be greater than one. Other challenges include long paybacks and difficult customer economics, as well as customer risk (such as warranty issues and the danger of a product quickly becoming obsolete because of the rapidly evolving technology).

As for SSL's impact on utility energy efficiency programs, there are a lot of inquiries from interested customers and companies looking to get incentives for their projects, but most utilities are not equipped to test products and verify their performance. Consequently, there is limited guidance for customers in selecting products, and it's difficult to separate the wheat from the chaff.

Hamann said that ComEd is closely monitoring the technology through DOE's SSL initiative. ComEd is making limited prescriptive offerings for LED products (exit signs, ENERGY STAR-compliant downlights and fixtures, and niche applications such as channel signage). It takes a conservative approach to custom LED solutions, which must pass the TRC test and meet payback requirements, meet IES-recommended light levels, and be tested by independent laboratories in order to qualify for incentives, which are based on energy savings.

Next came Cota of National Grid, one of the largest electric and gas utilities in the northeast, serving more than 3.5 million customers. She discussed National Grid's retrofit and new construction initiatives for LED downlights, as well as a performance lighting initiative for new construction and extensive renovation projects. "We feel we can help transform the market, the more incentives we offer," she said.

She stated that National Grid's initiative for LED downlights offers an incentive of $123 per retrofit fixture with a minimum of 21 watts saved, and a rebate of $40 per fixture for new construction. Their Design 2000plus Performance Lighting initiative for new construction provides $1.20 per watt saved below allowed state energy code, with the criteria of 15 percent reduction of lighting power density (LPD) expressed in Watts/sq. ft, over the interior power allowance obtained from the state energy code.

Cota noted that lighting levels must be maintained in accordance with IES recommendations, and various documents must be provided, including a ComCheck compliance report, a lighting fixture schedule with manufacturer's model number and rated wattage, and a performance lighting worksheet. Fifty percent of the lighting systems (calculated as percentile of the total wattage) incorporated in the design must be of a specified high-efficiency type, including LED.

Cota was followed by Whitney-Schulte of WECC, which administers and implements energy efficiency and renewable energy programs for utilities and state and local governments across the Midwest that serve more than 15 million customers. WECC programs provide education, technical expertise, and financial assistance. One such program is Wisconsin's "Focus on Energy."

Characterizing WECC's approach to SSL as "cautiously optimistic," Whitney-Schulte said they provide education on SSL technology, use ENERGY STAR as a model for performance, mitigate risk for program sponsors by only promoting quality LED products, and work on test sites and case studies.

She noted the challenges, such as long paybacks, a limited list of ENERGY STAR-qualified products, daily inquiries from vendors and customers, the amount of time it takes to verify the eligibility of non-listed products, and huge variations in product quality. “We want to make sure that these products are really going to deliver what the customers are expecting,” she said.

Whitney-Schulte discussed some SSL incentives offered by Wisconsin’s Focus on Energy initiative, which involve such applications as holiday lights, downlights, and commercial freezer cases. She noted that in the latter category, WECC has given out $25 rebates on 3,700 LED-lit freezer doors since 2007.

Finally, co-presenters Gibson of NRECA and Carney of Outsourced Innovation discussed the use of SSL incentives by electric co-ops in rural areas, especially for dusk-to-dawn security lighting, agricultural applications, and community and commercial use.

NRECA is a national organization dedicated to representing the interests of electric cooperatives and the customers they serve. Gibson noted that there are 930 such co-ops serving 42 million people in 47 states, covering 75 percent of the nation’s area, and that these co-ops see efficient lighting as an opportunity to engage every consumer in cost savings and load management. He outlined NRECA’s near-term goals to identify SSL applications that are customer-ready, engage with communities and key customers in demonstrations, and analyze the strategic role for LEDs alongside other technology and service options in meeting goals for efficiency and demand response.

Gibson noted that NRECA is looking closely at area lighting and testing four LED products at two co-op locations, with additional tests planned in 2009-2010 at four more co-op sites. Parameters being examined include ease of installation, real-world performance, energy use, human perception of light quality, price point for commercial investment, and dark-sky compliance.

Carney presented the results of an SSL parking lot demonstration along with lessons learned — for example, that fixture performance varies widely, that optics affect configuration, that nature (snow, lightning, etc.) can play havoc with equipment, and that education is the key. She also emphasized the importance of fact-based research, and of mitigating risk that comes with innovation by evaluating products side by side — and not just a few products, but in large enough quantities to provide meaningful results. Carney also talked about the value of showing customers that emerging technologies are being looked at to reduce costs. “Our data clearly show that LEDs have an early potential to create a real value proposition for a utility,” she said.

		LED A	LED B	High Pressure Sodium (250 watts)	LED C	LED D	Mercury Vapor (250 watts)
Energy Savings & Quality of Power	KWh savings	59%	66%	-	32%	54%	
	Power Factor				.827	.798	.444 leading
	THD				20.4	14.9	21.86
Photometry- *Photopic/Scotopic*	Av IL	.4/.7	.2/.4	.4/.3	1.7/3.0	1.1/2.2	1.6/1.4
	Max to Min	13/25	6/11	17/11	12.7/10.8	92.0/172.0	58.0/51.0
	Coefficient of Variation	.3/.6	.1/.3	.39/.24	1.05/1.06	1.91/3.74	1.08/1.06
	Uniformity	3.6/6.8	2.3/4.0	3.9/2.9	5.8/5.0	11.1/22.0	16.0/14.3
Subjective Assessment	Brightness	65	30	22	60	43	23
	Identify People	83	52	26	77	60	35
	Glare	59	63	48	80	40	60
	Safety	73	17	9	60	18	2
Financials	NPV	$1,635	$2,136	$1,872	$1,349	$1,641	$2110
	ROI	10 years	14 years		5 years	8 years	
	IRR	10%	5%		22%	13%	

Figure 5: Results of NRECA Parking Lot Study

9. PANEL 4: OUTDOOR STREET AND AREA LIGHTING

Jason Tuenge, Pacific Northwest National Laboratory (Moderator); Michael Barber, City of Anchorage, Alaska; Scott Wentworth, City of Oakland, California; Ralph Williams, Walmart

The panel began with Barber. Alaska's cold climate presents a special set of challenges for any street-lighting technology, and Barber described Anchorage's experience in beginning a three-phased plan to retrofit its streetlights to SSL. "We decided we need to save money now," he said, noting that there are 16,500 streetlights in Anchorage, and that three types of HPS wattage are used, depending on the roadway: 150 watts for residential streets, 250 watts for collector roadways, and 400 watts for arterial roadways.

Barber said that Phase 1 of the plan will retrofit all city-owned residential streetlights and low-speed collector lights; Phase 2 will retrofit parking lot lights (with controls), parking garages (with "smart lights"), decorative and historic fixtures, and trail lighting (with controls); and Phase 3 will retrofit utility-maintained residential and collector lights as well as high-speed arterial roadway lights.

He discussed the utility issues arising from the switch to SSL street lighting, such as how to depreciate the new hardware, how controls and dimming affect the schedule, and who should do the retrofit work. Barber said the total capital outlay for the project is nearly $2.2 million, and that it's projected to cut energy use by 50 percent and save $350,000 annually, with a seven-year payback period.

He explored the significant role control systems can play in enhancing the benefits of LED street-lighting, and noted that he and his colleagues anticipate an extra 20-percent

savings just from curfew and seasonal dimming. “It’s really incredible what you can do right now with controls,” he said. “We’re really actively looking at controls as a way to increase our efficiencies and our payback periods.”

Barber described two separate studies that were conducted on Anchorage residents, in which LED and HPS streetlights were compared. In the first study, which looked at perception of color temperature, the residents overwhelmingly preferred white LEDs over HPS luminaires. In the second study, which compared visibility measured as detection distance, a 250-watt HPS luminaire was outperformed by an LED luminaire of as low as 150 watts.

Residential roadway visibility demonstration in Anchorage, Alaska

Barber was followed by Wentworth, who recounted Oakland’s pilot experience replacing a few of its HPS streetlights with SSL. One street was lit with cleaned and relamped HPS, another with LED, and a third with both, split in the middle so the two technologies could be easily compared side-by-side.

Wentworth said the pilot study yielded "impressive" results that warrant further exploration — in terms of such factors as energy efficiency, light distribution, and light uniformity.

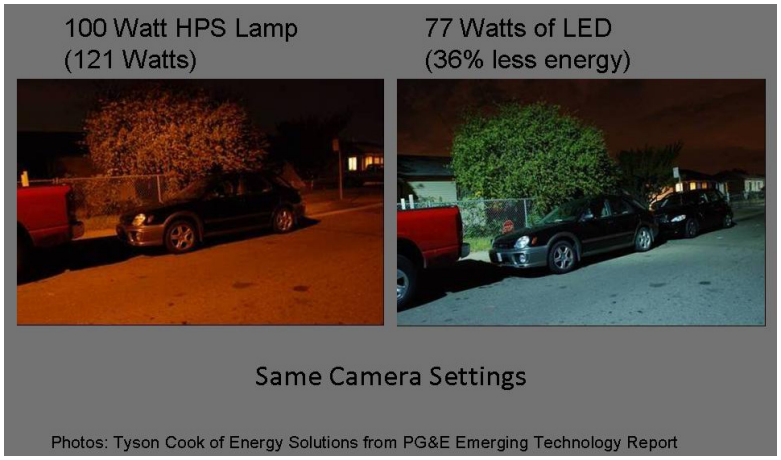


Figure 6: Comparison of HPS and LED Streetlights in Oakland

Wentworth highlighted some desired elements that were found to be lacking in the LED products he and his colleagues reviewed, and he also delved into some issues those products did not fully address that were felt to be pivotal to getting buy-in. Among those elements were innovative warranties, lumen maintenance, utility grade power measurement, tuning after installation, and late-night dimming.

Wentworth emphasized a number of SSL's potential advantages, such as using lumen maintenance equipment, monitoring LED status with bi-directional power measurement equipment, and dimming during late-night periods of low traffic. He said that taking maintenance savings into consideration and having power measurement equipment that sent accurate signals about an LED luminaire's status would increase the 15-year savings to $980 per luminaire.

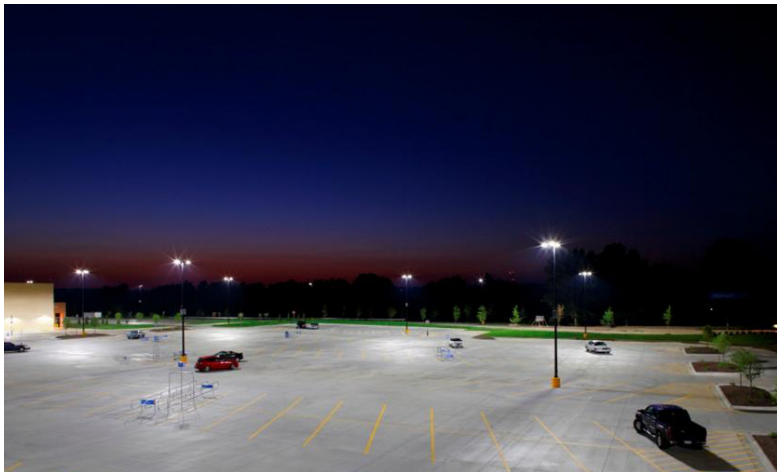
Since Oakland has about 35,000 streetlights, most of them HPS, Wentworth concluded that switching to SSL street lighting has the potential to cut down on energy use, both directly and by facilitating better control, such as late-night dimming with overrides, and also to lower maintenance costs, reduce light trespass, and create "green" jobs.

Wentworth was followed by Williams, who discussed Walmart's trial use of LED parking lot lighting. He noted that this use is motivated by multiple goals. In addition to saving energy and cutting down on maintenance, Walmart hopes to reduce light trespass and other wasted light, which in many places is subject to strict local ordinances, and also to improve visibility and reduce hazardous waste.

Williams said that in its use of LED parking lot lighting, Walmart has relied on the LED Site Lighting Performance Specification developed by the DOE Commercial Building Energy Alliances, in which Walmart has played a key role. He described a parking lot

pilot study at a Walmart in Rogers, Arkansas, where some of the HID lights were replaced with LED luminaires, and where lighting was found to be more uniform and controllable and to provide better illuminance. Williams pointed out that although LED lighting reduced energy use by more than 65 percent for an annual savings of nearly $5,000, it was the maintenance savings that made it cost-effective in that particular setting, because Walmart replaced the HID lamps every two years.

He also discussed Walmart's first full-site evaluation of SSL in the parking lot of a supercenter in Leavenworth, Kansas, noting that first impressions at the site were very positive: light distribution was very uniform, onsite glare was acceptable and better than with metal halide lights, offsite glare looked good after small house-side shields were installed, the store looked approachable and safe, and the store's façade looked good.



Uniform light distribution using LEDs in a Walmart parking lot in Leavenworth, Kansas

Williams emphasized that store geometry, local ordinances, and acquisition costs determine whether SSL is the right solution for a given location. "We're seeing a three- to six-year payback (with LED parking lot lights)," he said. "To roll it out across our chain, it's going to have to get a little bit better."

The panel concluded with Tuenge reviewing the ENERGY STAR criteria for outdoor SSL luminaires. He noted that draft criteria were issued July 1 and the comment period ends July 31, with final criteria expected in late 2009.

Tuenge reviewed the three separate categories of the criteria: outdoor pole-mounted area and roadway luminaires, outdoor wall-mounted area luminaires ("wall packs"), and parking garage/canopy luminaires. He noted that the criteria have been revised in response to industry feedback to first-draft criteria released a year before, that CALiPER testing has revealed a wide range of performance, and that demonstration projects indicate the potential for energy savings as well as the need for performance guidelines.

Tuenge outlined the changes to the draft criteria for each category and discussed Fitted Target Efficacy (FTE), a new metric created by DOE for evaluating the performance of outdoor area and roadway lighting, which had not been adequately conveyed by existing metrics. He explained that this kind of lighting requires a particularly complex discipline

of design and specification to provide required light levels without producing light trespass, sky glow, or glare that can impair drivers and pedestrians.

Tuenge noted that FTE differs from luminaire efficacy in that it makes a distinction between useful lumens and those that might cause glare, wasted light, or light trespass. He observed that it is application-independent rather than being subject to site-specific conditions such as required illuminance levels or mounting height, and that it is based on the assumptions that for most roadway and area lighting applications, a rectangular distribution pattern minimizes overlap and spillover, and that a luminaire's area of coverage can be defined as the area illuminated to IES-recommended uniformity ratios.

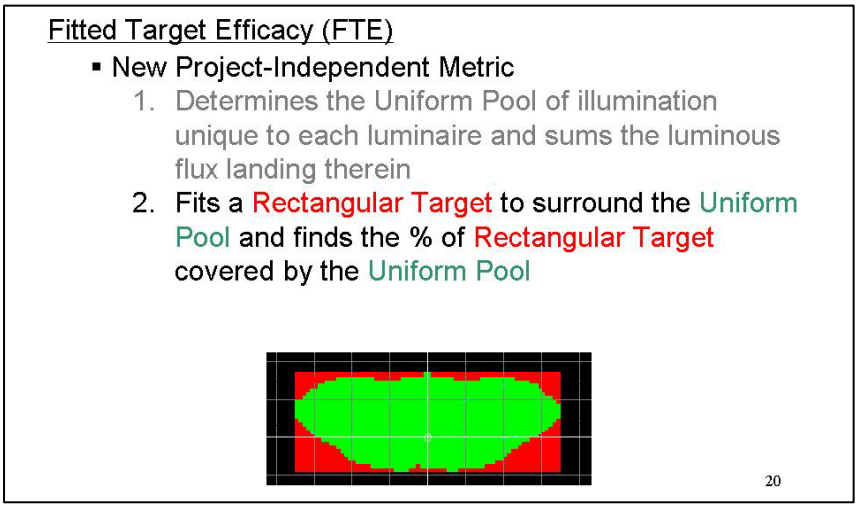


Figure 7: Fitted Target Efficacy

Tuenge pointed out that FTE is applicable to all pole-mounted outdoor luminaires regardless of IES luminaire classification, and that because it is calculated using standard absolute photometry, no additional testing is required. He also provided a number of technical details to further explain the ENERGY STAR for SSL criteria.

10. PANEL 5: DESIGNING WITH LEDS

Marsha Turner, International Association of Lighting Designers (Moderator); Derry Berrigan, Derry Berrigan Lighting Design; Dan Blitzer, The Practical Lighting Workshop; Avraham Mor, Lightswitch Architectural; Emily Klingensmith, Schuler Shook

Panel 5 was moderated by Turner of the International Association of Lighting Designers, which works closely with DOE's SSL program. Because client satisfaction is their highest priority, lighting designers provide an important practical perspective on SSL.

After an introduction by Turner, Blitzer spoke about LED luminaires in application. "The value of lighting to the people using it far exceeds the cost of the energy to operate it," he said. Blitzer explored the issues of luminaire efficacy, application efficacy, color, and lifetime, and discussed the *Next Generation Luminaires* competition.

Blitzer noted that LEDs perform well in applications where they're close to the target, the environment is cool, the lighting requirement is low, and there are no conventional options. "The most successful applications (of SSL) exploit multiple benefits," he said. Blitzer focused somewhat on LED downlights, which is one application where LEDs are competitive with the incumbent technology.

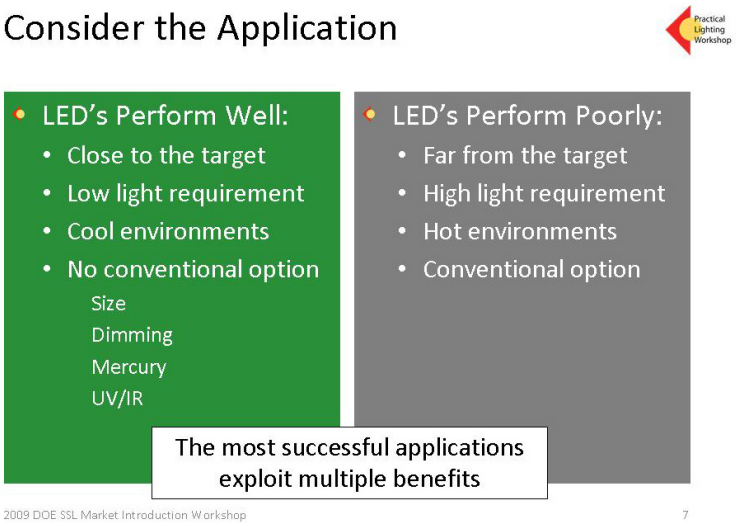
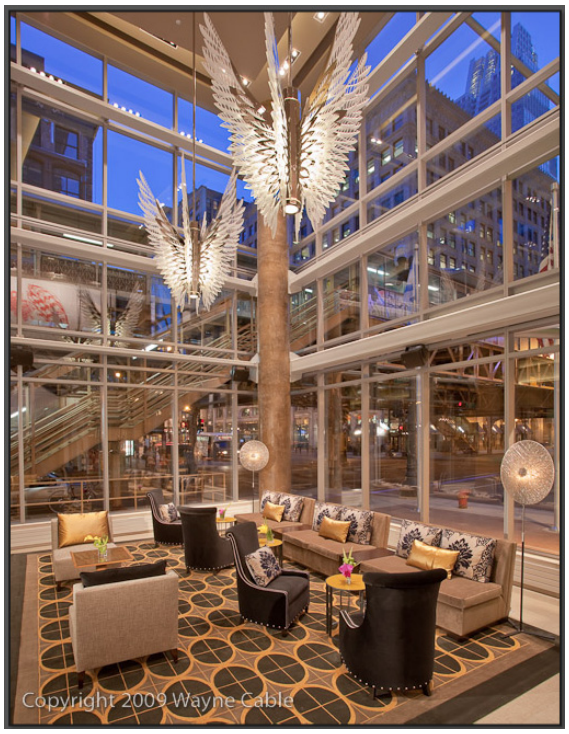


Figure 8: Consider the Application

Next, Mor shared his experience in designing with LEDs and compared the pros with the cons. Among the arguments he cited in favor of using LEDs were longer life, the fact that many clients want to use them, design maintenance, and the fact that there is no better way to do color changing. Arguments against using LEDs included high cost, flicker, and lack of simple dimming. Also cited in this regard were a lack of installer and manufacturer knowledge, as well as issues regarding warranties and color control.



LED installations at the New Wit Hotel in Chicago.
Photo ©2009 Wayne Cable, SelfMadePhoto.com

Mor described several LED installations in detail, including the Wit Hotel in downtown Chicago. He urged component manufacturers to come up with a driver larger than 100 watts, as well as a dimming driver larger than 25 watts; and expressed the need for brighter LEDs. Addressing luminaire manufacturers, he emphasized that LED luminaires need to be serviceable, that 0-10v dimming is too complicated and costly, and that misreading drawings creates bidding errors.

Mor noted his company's requirements of SSL vendors, including LM-79 photometry, at least two samples of the same CCT, a written luminaire binning policy and end-of-life policy, as well as ENERGY STAR and Lighting Facts labels. Mor's firm requires these before it will meet with any manufacturer. He also discussed the issues of spares and warranty requirements, emphasizing that there needs to be a way to hold manufacturers' feet to the fire in case something goes wrong. Mor invited attendees who have questions about the use of SSL in various applications to make use of the expert knowledge of IALD members.

Next, Klingensmith presented three case studies where LEDs were considered as a possible solution. The first case involved illuminating the graphics niches in a corporate office. For this application, fluorescent strip lights were selected over LEDs because of the cost factor. The LED luminaire considered cost $115 per foot, compared to $22 per foot for the fluorescent light, which gave good light distribution in addition to being significantly less expensive.

The second application Klingensmith described involved light box panels in a law office. She explained that here, the goal was to create a soft and subtle light by illuminating the wall behind the panel so that it would be reflected out through frosted glass. Klingensmith noted that because the panels were 10 feet high, the fluorescent T5s that were considered couldn't be controlled sufficiently to provide uniform light from top to bottom, whereas the LEDs could. She said that for this reason, they chose to use the LED solution, which also proved to be less expensive than the fluorescents ($100/foot versus $123/foot).

The third case study involved outdoor display niches at the Illinois Holocaust Museum and Education Center. Klingensmith noted that Schuler Shook never considered anything but LEDs for that setting, because of limited space as well as LEDs' long life, directionality, and suitability for exposure to rain and snow. She also observed that this particular installation required a fair amount of coordination with the architect and contractors to work out the details.

The panel concluded with Berrigan, who began by describing her work with Walmart on the use of SSL in a prototype store, which she said is 68 percent below ASHRAE requirements. "Not only are we getting the lighting quality and energy efficiency benefits, but we're also increasing sales and decreasing the ecological footprint," she said, noting that it didn't cost any more to use LEDs at the prototype Walmart store than traditional lighting technology.

Berrigan said that she's currently studying the effects of LED lighting on the shelf life of grocery produce, and emphasized the importance of education all along the lighting chain. Interestingly, she shared that produce sales can equal the dry goods sales, and if you illuminate it right, you can improve the customer experience, increase sales, and reduce the effects of WV and IR.

She then described a project in which she replaced 97 percent of the lighting in a McDonald's in Carey, North Carolina, with SSL. She observed that the restaurant is 62 percent below ASHRAE on the interior and 70 percent below ASHRAE on the exterior. The LED solution cost the same as the metal halide solution it replaced, while reducing total wattage from more than 12,000 to 1,200. Berrigan also shared that one of the biggest obstacles to market adoption of SSL is finding a way to take a bigger leadership role in green technology training. During this project, she was on ladders helping the crews get the lighting installed, evidence that there's a real need for training in these new technologies.

Lighting quality plus energy efficiency equals lighting sustainability. "What this project shows is that we can maintain lighting quality, attain energy efficiency, and do it in a cost-effective, practical way," she said.

11. PANEL 6: LED RELIABILITY

Eric Richman, Pacific Northwest National Laboratory (Moderator); Mark Hodapp, Philips Lumileds Lighting Company; Steven Briggs, GE Lumination

The panel was kicked off by Richman, who briefly reviewed the topic of LED reliability, making the point that historically, reliability has been assumed to be covered by lamp life, but that the uniqueness of LEDs forces a different approach that also takes into consideration other factors, such as the driver, electrical circuitry, and fixture components.

He stated that true LED life is the same as overall luminaire reliability, which requires quality historical data, but that quality historical data is not yet available for LEDs. Richman reviewed the reliability testing being done by DOE's CALiPER program, which looks at lumen maintenance, efficacy shift, color shift, and other failures that occur over long-term operation as well as also examining other reliability-related issues.

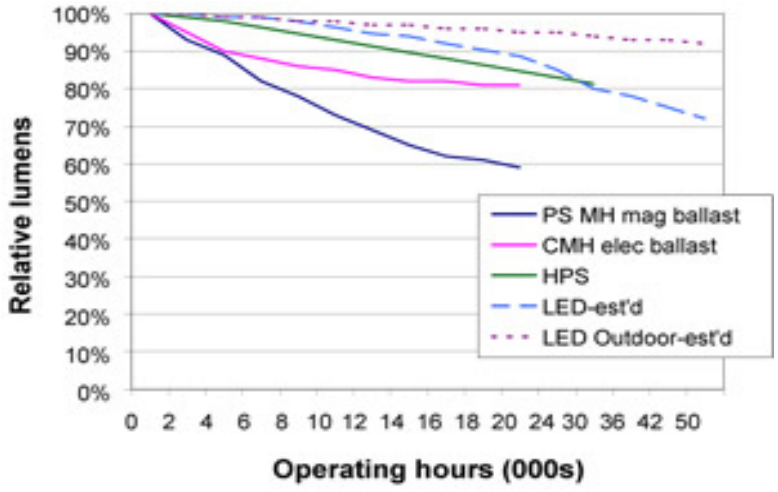


Figure 9: Lumen Maintenance as "Life"

Examining the question of lumen maintenance, Richman discussed IES LM-80 and TM-21 as pieces of the puzzle, and then looked at color shift and other patterns of LED performance change over time. He discussed combining the "B" and "L" metrics as one possible option to define overall reliability. Richman explained that the L metric gives the current lumen output as a percentage of the initial lumen output, and that "L_{70}", which indicates that lumen output has fallen to 70 percent of initial output, is the L metric most often used, because the average human eye can't detect a decline in lumen output of less than 30 percent. He explained that the B metric indicates the time to failure of a given sampling of luminaires, and that "B_{50}", which indicates the point in time when half the product has failed, is the B metric that's most often used. Thus, "L_{70}/B_{50}" indicates the point in time when half of the product has degraded to 70 percent of initial output. Richman emphasized that the B metric needs to include the failure of common components such as the driver, fixture, and circuitry, and not just the LEDs.

Richman was followed by Hodapp, who talked about designing LED products for reliability, examining the issue in terms of Philips' LUXEON Rebel LED product and focusing on lumen maintenance, catastrophic failures, and combined L70 and catastrophic failures. He noted that LEDs can fail catastrophically, especially when driven at very high junction temperatures and drive currents, and that catastrophic failures can be reduced with lower stress conditions. Hodapp also observed that large arrays of LEDs can benefit from redundant design concepts, so that a single failure does not result in a cascade effect.

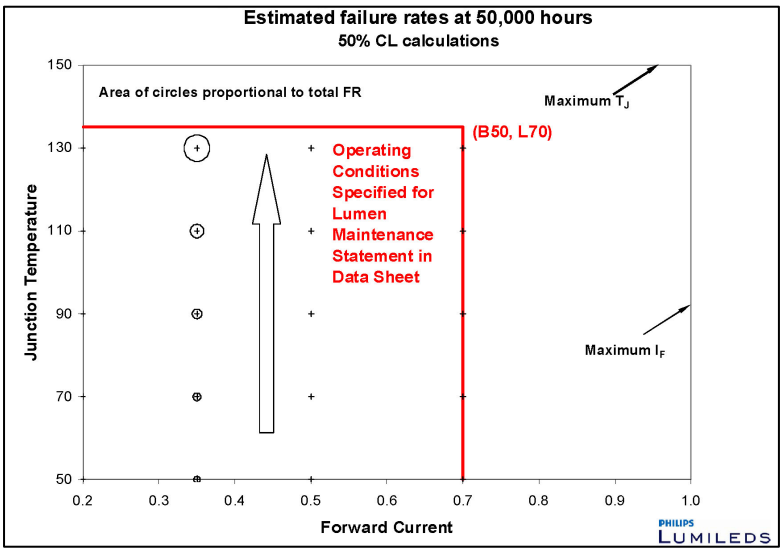


Figure 10: Impact of Driving at Higher Temperatures

Hodapp made the point that, in general, the reliability of the LED is a function of drive current and LED case temperature, and that the impact of a single LED failure on the reliability of the system depends on how the LEDs are wired together. He cited solder joints, electrical drivers, and external lens and optics as possible causes of failure besides the LEDs. Noting that overall system reliability is only as good as the weakest link, he

described a model developed by Philips that predicts catastrophic failure and lumen maintenance.

The panel concluded with Briggs, who emphasized the need to consider both the product and the process when designing LED luminaires for reliability, and to learn from failures to determine their root cause. He described GE's approach to reliability, which includes a "tollgate process" that enforces checks and balances, as well as a "top-down" approach that takes into consideration the system, subsystem, and component, and that breaks down the design to key factors. Briggs noted that one of the tools GE uses is accelerated testing, which allows designers to make predictions about the life of a product by developing a model that correlates reliability under accelerated conditions to reliability under normal conditions.

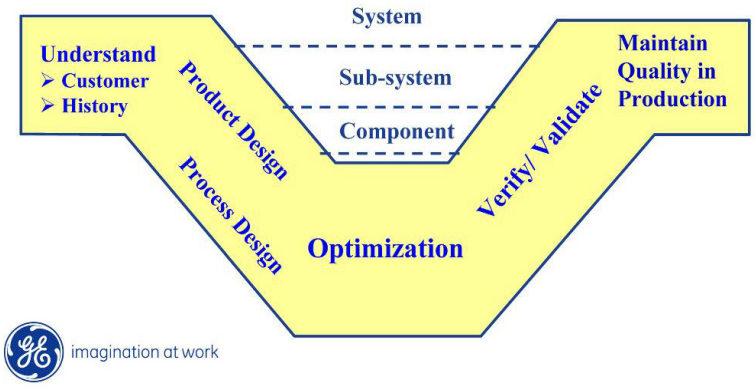


Figure 11: GE Approach – Design for Reliability

Briggs concluded that a successful approach to reliability includes such things as comprehensive and measurable specification, modeling and design simulations, and execution of the verification and validation plan on an adequate sample size. He emphasized that lumen depreciation over time is just one aspect of overall reliability, which also involves such changes as color shift, upward shift in power consumption, intermittent operation, and catastrophic failure.

12. PANEL 7: COST EFFECTIVENESS

James Brodrick, U.S. Department of Energy (Moderator); Bruce Kinzey, Pacific Northwest National Laboratory; Dan Weinheimer, City of San Marcos, California; Chris Granda, Vermont Energy Investment Corporation

The final workshop panel was kicked off by Brodrick. He gave a brief overview of the issue of cost-effectiveness, noting that high costs remain the biggest hurdle to market acceptance of SSL, that LED technology is continually getting better and cheaper, and that some applications are beginning to look competitive with the incumbent technology. He pointed out that multiple factors affect decision making on lighting systems, including first cost, energy savings, maintenance savings, incentives and rebates, the financial criteria of the site owner, and the demands of the particular application.

Brodrick was followed by Kinzey, who shared his perspectives on cost effectiveness in DOE's GATEWAY program, which demonstrates new SSL general-illumination products in real-world applications. GATEWAY seeks to field-test products that save energy, match or improve the illumination of conventional products, and are cost-effective for the user.

Kinzey noted that of these three criteria, cost-effectiveness is the most difficult to achieve, particularly after the first two have been met, and that at present it is typically achieved through anticipated maintenance savings. Energy savings by itself is insufficient motivation for much of the market, in part because of the relatively low cost of energy in the U.S., so there's an increasing need to identify and quantify the value of the other benefits of SSL. These, he said, include such things as longer life, reduced maintenance, superior control, and other advantages that have yet to be documented.

To illustrate how these kinds of benefits can transcend the cost issue, Kinzey made a cost-value comparison of a 1978 Corvette and a 2008 Corvette. Over the course of 30 years, the Corvette's horsepower more than doubled, its fuel economy increased by 50 percent, emissions improved significantly, the sound system became much more sophisticated — and cars in general became much safer, more durable, and more reliable. At the same time, the cost of the car in today's dollars increased by 50 percent or more, yet people still buy it. Kinzey's point was that once users get a taste for a technology's new capabilities and benefits, they're willing to pay substantially more and aren't interested in doing without the improvements.

He pointed out that LED technology and controls are different from those of conventional technologies, and that therefore SSL may always cost more than conventional lighting. He also noted that there's a much stronger correlation between output and price with LED products than with conventional technologies, because higher lumen output generally means more LEDs, more heat sink material, larger housing, and so on.

Kinzey also made the point that conventional technologies are not without their own problems, which have come to be accepted by users, and that the maintenance costs of conventional products are often not well documented. He remarked on the fact that conventional lighting technologies have the advantage of maturity over SSL, because

they've been on the market for so much longer and have achieved a relatively high level of efficiency as well as standardization of manufacturing and distribution. "It's a tough market for a new technology to break into," he said.

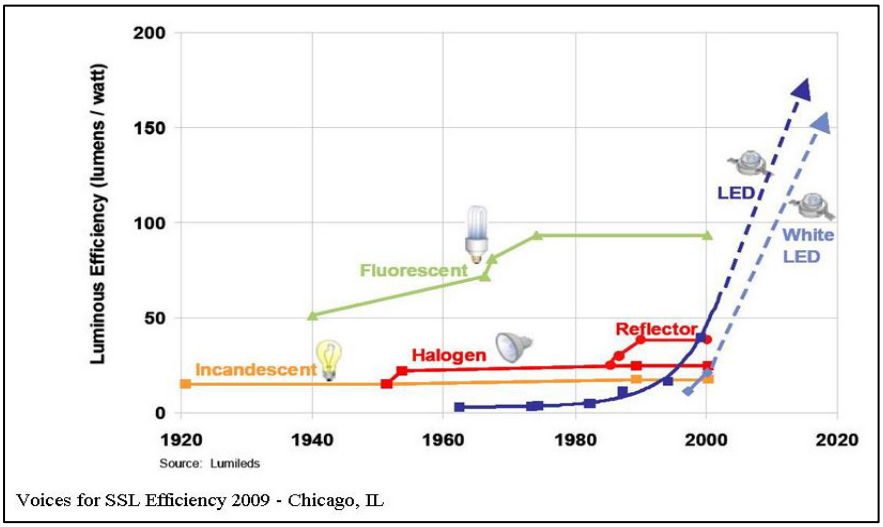


Figure 12: The Potential Is There with LEDs

Kinzey observed that rapid progress continues in both the performance and price of LEDs, and that both of these drive cost-effectiveness. A lot of potential benefit remains from further improvement of LEDs, particularly from a societal standpoint, he said. Kinzey stated that diminishing returns will make it increasingly difficult to justify additional investment in LED lighting on an individual basis, if it's based only on the value of the energy saved.

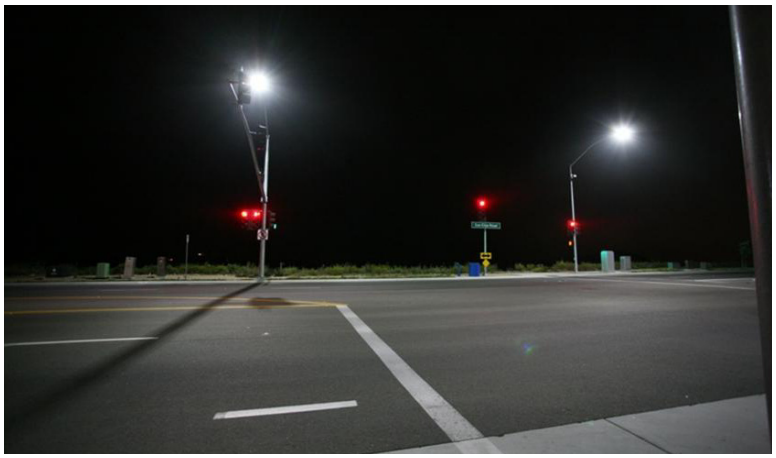
Kinzey was followed by Weinheimer, who discussed the beta testing of LED street lighting in San Marcos, a north San Diego county community with about 83,000 residents. He explained that the testing is being conducted by the local utility, San Diego Gas & Electric, and that the city's primary goals are to save money and electricity through either induction or LED lighting, but that there are secondary goals as well. One such goal is to increase public safety, and Weinheimer mentioned that the police department was excited about the LED lighting because it gave enhanced color recognition at night.

He said that because of California regulations, San Marcos is required to reduce greenhouse gas emissions, and cutting down on electricity use is one way to do this. He explained that because San Marcos has a rural lighting standard, there are streetlights only at intersections and decision points along the roads. San Marcos also has dark-sky concerns due to the city's close proximity to Palomar Observatory.

Weinheimer said that another reason for the beta testing is that, with more than 400 acres of undeveloped municipal land slotted for development, he and his colleagues wanted to find out whether LEDs would be suitable for use in a variety of settings, including single-

family residential, multifamily residential, parking lots, parking garages, commercial zones, intersections, and parks.

In his presentation, Weinheimer examined the cost-effectiveness of LED streetlights and noted that each one costs $1,025, compared with $585 for induction lights, but that other factors come into play. These factors include the existing light inventory, reduced electricity demand, lifespan, maintenance, inventory efficiency, and incentives or rebates from the local power utility.



Beta testing of LED street lighting in San Marcos, California

Weinheimer raised the issues of lifespan guarantees, as well as the life and scope of the warranty, and discussed financing strategies. “As a city, we strongly believe that projects should pay for themselves,” he said.

In conclusion, Weinheimer cautioned that not all products are equal and advised other municipalities that are interested in LED street lighting to test each product before making major purchases. He also advised them to secure a long and comprehensive warranty, and to develop studies to indemnify local government against liability issues, which he cited as a concern.

The panel concluded with Granda, who presented the utilities’ point of view, focusing on how energy efficiency program sponsors decide whether an energy efficient product is cost-effective, and which characteristics of SSL products affect this incentive decision.

He explained that to determine whether a product is cost-effective, installation labor, maintenance and replacement costs, electricity, the cost of time, and other costs (such as externalities and program costs) are added to the initial capital expenditure, to come up with the total cost of the lighting service.

Granda discussed several economic assumptions made in determining cost-effectiveness. One of these assumptions is that everything has a known or quantifiable price, including electricity, technology, maintenance, time, and the environment. Another assumption is that all expenses can be converted to streams of costs; and that simplifications in the face of unknowns are permissible.

He reviewed commonly used cost-effectiveness tests, and noted that their use depends on public policy, usually at the state level. Then he discussed a real-world evaluation of costs to benefits that involved LED outdoor area lighting at a Vermont Holiday Inn. Granda noted that the SSL system showed a savings over the MH system in electricity, replacement equipment costs, and labor, and that even though SSL was more expensive, it cost less when amortized over a 20-year period and was clearly the winner.

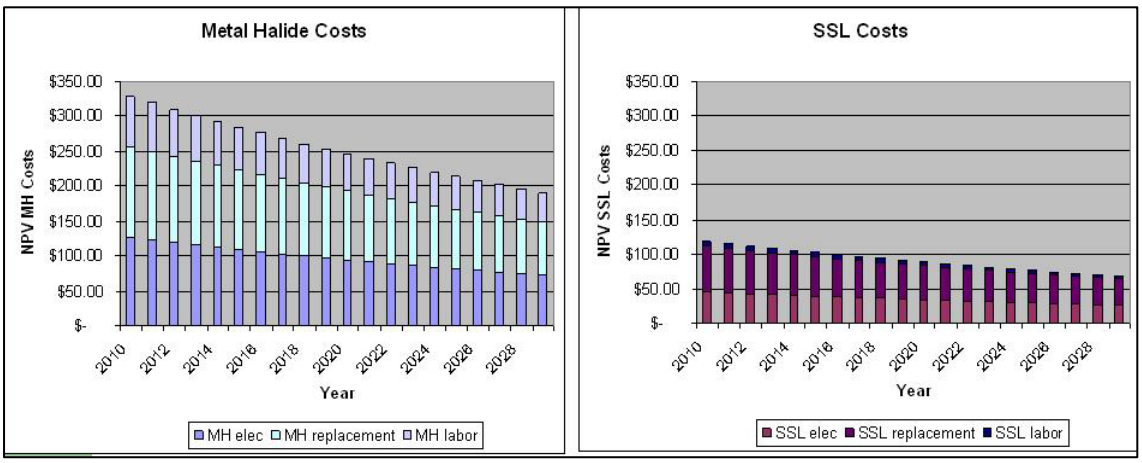


Figure 13: Net Present Value Comparison of MH vs. SSL Area Light

Granda then applied this total resource cost test to the *L Prize* competition and determined that the *L Prize* winner will need a price tag of $10 or less in order to compete with CFLs. He closed by emphasizing that right now, the most cost-effective implementations of SSL are for commercial luminaires, because they make the most of high-efficiency gains and a high number of operating hours.

13. NEXT STEPS

Looking forward, the U.S. Department of Energy will continue to work closely with the solid-state lighting industry, energy efficiency organizations, utilities, and standards organizations to guide market introduction of high-performance SSL products.

Following the July workshop, DOE announced plans to form a solid-state street lighting consortium, to leverage the efforts of multiple cities pursuing evaluations of LED street lighting products. The DOE Consortium will provide a forum for entities with similar backgrounds and needs to share information, ask questions, and tap into a large body of knowledge and experience that will help maximize the value of dollars spent evaluating LED street lighting. Membership will be open to municipalities, utilities, and energy efficiency organizations. More details will be available soon at www.ssl.energy.gov/ssl/gatewaydemos_consortium.html.

In August, DOE published the initial report from a ground-breaking demonstration of LED roadway lighting on the I-35W bridge in Minneapolis, Minnesota. This GATEWAY

demonstration report provides an overview of initial project results including lighting performance, economic performance, and potential energy savings. Visit www.ssl.energy.gov/gatewaydemos_results.html to download this report, as well as new reports on demonstrations of freezer case lighting in Eugene, Oregon, and street lighting in Portland, Oregon.

Also in August, DOE implemented a new online search system for CALiPER detailed reports, timed with the release of the Round 8 detailed reports. This advanced search capability allows users to more easily view and compare test results. In October, DOE published the CALiPER Round 9 summary report; the Round 9 detailed reports are expected in November. Visit www.ssl.energy.gov/caliper.html to use the search system and download reports.

In September, the 2009 *Lighting for Tomorrow* residential design competition winners were announced at the American Lighting Association annual conference. The judges selected two Grand Prize Winners: Cree LED Lighting's High Output Six-Inch Downlight and Philips Color Kinetics eW Cove Powercore. The judges also recognized five other entries with Special Focus Awards for their successful incorporation of important design considerations:

Design Element	**Special Focus Award**
• Light Distribution:	MaxLite LED Architect Flat Panel
• Versatility:	Lightolier Calculite Solid-State
• Ease of Installation:	Creative Systems Lighting Eco Counter
• High Efficiency:	Cree LED Lighting High Efficacy Six Inch Downlight
• Technical Innovation:	Cree LED Lighting SSL Track Fixture

More information on the winning entries is available at www.lightingfortomorrow.com.

Also in September, DOE received 249 'intents to submit' for the 2009 *Next Generation Luminaires* commercial design competition. Judging will take place in December, and the winners will be announced at the Strategies in Light conference in February 2010. Learn more at www.ngldc.org.

September marked a major milestone for the *L Prize* competition when DOE received the first entry, an LED replacement for the 60-W incandescent bulb from Philips Electronics. Philips developed this product in response to DOE's industry-wide challenge to spur development of high-quality, high-efficiency LED replacements for the common light bulb. This first entry will now undergo rigorous evaluation, including photometric testing and field assessments, before a winner is declared. Learn more at www.lightingprize.org.

In addition, the Lighting Facts program continues to grow, as more and more manufacturers, retailers, and lighting professionals take the pledge to assure and improve the quality of LED lighting products. To date, 207manufacturers have pledged to use the Lighting Facts label and guidance to document the performance of the products they manufacture. In addition, 47 retailers and distributors, and 53 lighting professionals

(utilities, energy efficiency groups, lighting designers, and specifiers) have agreed to look for and use products that bear this label. Learn more at www.lightingfacts.com.

Finally, to stay apprised of DOE SSL program activities, progress, and events, register for ongoing updates at www.ssl.energy.gov. Look for an SSL Update on the 2010 SSL Market Introduction Workshop, planned for July 2011 on the West Coast.

APPENDIX: Attendee List

DOE SSL Market Introduction Workshop
Chicago, Illinois
July 13-15, 2009

Teren Abear
Southern California Edison

Gilles Abrahamse
eldoLED America Inc.

Dan Agne
Wisconsin Energy Conservation Corporation

Dave Ahlberg
MidAmerican Energy Company

Everett Aistrope
Task Lighting Corp.

John Akins
Tyco Electronics

Diane Allard
Akoya

Jennifer Amann
ACEEE

Mike Armstrong
GE Lighting Systems

Jim Anderson
Philips Color Kinetics

Abdul Aslami
Sharp Electronics Corp.

Michael Bandel
Heatron Inc

Michael Barber
City of Anchorage, Alaska

Tom Barnett
Masco Corp

Jay Bartek
Task Lighting Corp.

Laura Basili
ComEd

Mario Battello
Texas Instruments

David Baum
Lighting Science Group

Mark Bettin
MMPI

Derry Berrigan
Derry Berrigan Lighting Design

Vrinda Bhandarkar
Strategies Unlimited

Dave Birtalan
Optek Technology

Juan Carlos Blacker
Portland Energy Conservation, Inc. (PECI)

Oliver Blackwell
Low Energy Designs Limited

Monica Blakeslee
Ecos

Daniel Blitzer
The Practical Lighting Workshop

Eric Borden
Sea Gull Lighting

Joel Brassfield
Texas Instruments

Eric Bretschneider
Lighting Science Group

Steve Briggs
GE Lumination

Jeff Bristol
Westinghouse Lighting Corporation

Jim Brodrick
U.S. Department of Energy

Richard J. Bronson
Indak Manufacturing, Inc.

Chad Bulman
Midwest Energy Efficiency Alliance

Robert Burns
Straight Line Services

Jamey Butteris
Hubbell Lighting

Wayne Callham
BlueStar Energy Services

Todd Carlson
Pear Lights

Martha Carney
Outsourced Innovation

Kelly Carter
AmerTac

Michael Chan
Digital Lighting Inc

Marc Chason
Marc Chason and Associates, Inc.

Keagan Chen
Varian Semiconductor

Jason Chesley
CSA / OnSpeX

Nick Chintala
GE Lighting

Terry Clark
Finelite, Inc

Chris Cloutier
D&R International, Ltd.

Shana Cockerham
D&R International, Ltd.

Ilkan Cokgor
Intematix Corporation

Gary Colip
Advanced Control Technologies

Kelly Cota
National Grid

Shirley Coyle
Ruud Lighting Canada / BetaLED

Ryan Crabb
UMI

Ed Cronick
Sea Lion International

Jack Curran
LED Transformations, LLC

Lynn Davis
RTI International

Joe DeAngelis
Lunera

Charles DeVries
Texas Instruments

Dave Doyle
Luminus Devices

Ben Duggan
OptoElectronix

Kyle Dunn
MWE2

Ryan Egidi
DOE - National Energy Technology Laboratory

Sarah Ellis

Sonny Enriquez
Southern California Edison

John Essman
Ace Hardware

Allen Fann
Action Media Technology

Jorge Fernandez
The Home Depot

Bob Fiermuga
Eclipse Lighting Inc.

Tom Flanagan
Osram Sylvania

David Fleak
Tyco Electronics

Colette Fleming
Kenall

Alicia Forrester
ComEd

Joe Frazier
ACT, Inc.

Cheryl Fretz
Fluid Market Strategies

Vilma Galubickaite

Samir Gandhi
Advance Color Lighting, Inc.

Tom Geist
EPRI

Leo Geng
CAO Group

Jasper Gibbons
Micron Technology

Bob Gibson
National Rural Electric Cooperative Association

Lindsay Gillespie
StandardVision, LLC

Kevin Givens
Relume Technologies, Inc.

Kelly Gordon
Pacific Northwest National Laboratory

Christopher Granda
Vermont Energy Investment Corporation

Phil Grandinetti

Lari Granger
Duke Energy

Mike Grather
Luminaire Testing Laboratory, Inc.

Wendy Graves
Akoya

Derek Greenauer
D&R International, Ltd.

Garrett Grega
Philips Lighting

Tom Griffiths
Solid State Lighting Design

Frank Grobmeier
Ushio America, Inc.

Brian Halliwell
Lights of America

Mark Hamann
ComEd

Bill Hamilton
The Home Depot

Michael Handerhan
Toyota Tsusho America, Inc.

Greg Hansen
Balzhiser & Hubbard Engineers, Inc.

Patricia Harada

Kei Haraguchi
Nichia America Corporation

Gerard Harbers
XICATO INC

Tom Harold
Grainger

Eric Haugaard
BetaLED by Ruud

Nathan Heiking
Kenall

Mark Henderson
Ecos

Brian Hermes
Topanga Technologies

Karl Hilker
Wisconsin Energy Conservation Corporation

Dave Hinman
Miami Valley Lighting

Mark Hodapp
Philips Lumileds Lighting Company

Mark Homan
Relume Technologies

Shaun Horan
Universal Lighting Technologies

Rick Houle
Philips Gardco

Tim Howard
Lights of America

Kristi Hsu
Sunten Technology USA

Andrew Huang
LED Lighting

Charles Humphrey
International Applied Engineering

CY Hung
Texas Instruments

BT Hwang
HEP

CB Hwang
Fawoo Tech North America, LLC.

Danny Hyatt
LSI

Larry Ingenito
GSSI, Inc.

Joel Jacobson
Feit Electric Co., Inc.

Wendy Jaehn
Midwest Energy Efficiency Alliance

Warren James
Edward R. James Partner, LLC

Dr. Paulina Jaramillo
Carnegie Mellon University

Laurent Jenck
On Semiconductor

Troy Jenkins
CAO Group

Phil Jessup
The Climate Group

Jianzhong Jiao
Osram Sylvania

Scott "Ray" Johnson
Energy Efficient Group

Ken Jonas
Broan-Nutone LLC

Kevin Kampschroer
U.S. General Services Administration

Ken Kane
Lighting Services, Inc.

Richard Karney
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Toyoda Gosei

Kris Kido
Micron Technology

Youjin Kim
ETRI

Bruce Kinzey
Pacific Northwest National Laboratory

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Service Concepts

Emily Klingensmith
Schuler Shook

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Mike Kretzmer
Endicott Research Group

George Krouskos
GSSI

Di Labiak
Genesis LED Lighting

Gregg Labiak
Genesis LED Lighting

Sarah Lackas
Broan-NuTone, LLC

Gus Lanese
GE Lighting

Blake Lange
Millennia Technologies, Inc.

Roger Lange
Millennia Technologies, Inc.

Susan Larson
LedEngin, Inc.

Marc Ledbetter
Pacific Northwest National Laboratory

Charles Li
Virginia Optoelectronics, Inc.

Dustin Lilya
Supervalu, Inc.

Steve Lindberg
Rapid Electric, Inc.

Diane Lindsley
Wal-Mart Stores, Inc

Andrew Lindstrom
GE Lighting Systems

Andy Lipman
Next Generation Lighting

Ken Lively
Bulb Star

Leonard Livschitz
LedEngin, Inc.

Doug Lockard
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Nicholas Lovier
Ameren Illinois Utilities

Matt Lowe
Lilly

Miles Lu
UMI

Melissa Lucas
Northeast Energy Efficiency Partnerships

Robert Lucas
MOX

Jim Lucy
Electrical Wholesaling magazine

Vireak Ly
Southern California Edison

Mark Lynders
Westinghouse Lighting Corporation

Lynn Mantha
Broan-NuTone LLC

Karen Marchese
Akoya

Jim Marquardt
SRP

Patrick Martineau
Hydro-Quebec

Vladimir Maslov, PhD.
LEDRU

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David Mattocks
GreenPro Systems

Mark McClear
Cree

Michael McClear
Relume Technologies

Jeff McCullough
Pacific Northwest National Laboratory

Dan McGowan
Molex

Steve McMahon
Micron Technology

Chad McSpadden
H.E. Williams

Prem Mehrotra
General Energy Corp.

Jim Mellish
Purdue University

Mia Paget
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Erik Milz
Philips Lumileds

Scott Mitchell
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Erinn Monroe
ComEd

Avraham Mor
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John Morris
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Ralph Mosher
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Greg Mueller
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Greg Murphy
MaxLite

Kirsten Murray
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Michael Myer
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Wayne Myrick
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Robert Nachtrieb
Lutron Electronics

Bill Nagengast
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Judy Nagengast
Continental Inc.

David Nelson
Sol-Light, LLC

John Nettle
National Semiconductor

Dan Nguyen
Molex Inc. (SSL-BU)

Autumn Nieland
LightWild

Sandeep Nijhawan
Redpoint Ventures

Meredith Nole
American Efficient Lighting & Energy Management

Elizabeth Noonan
Midwest Industrial Lighting

Kevin Noonan
Midwest Industrial Lighting

Mike Noonan
Midwest Industrial Lighting

Aaron O'Brien
Pure Lighting

Brian Owen
greenTbiz-LEDs Magazine

Irfan Parekh
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Brett Parker
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Doug Paulin
Leotek Electronics USA

Jamie Peters
Midwest Energy Efficiency Alliance

Raj Pillai
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Chantal Pittman
io Lighting

Gerald Polk
DTE Energy

Jason Pomante
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Nick Poplawski
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Derek Publicover
GE Lumination

Jon Quigley
Pear Lights

Sarah Rambacher
Toyota Tsusho America, Inc.

Mohammed Razzak
Lights of America

Jeff Rehm
Grainger

Scott Riesebosch
CRS Electronics

Janet Reiser
Sea Lion International

Ann Reo
io Lighting

Dasha Rettew
The Climate Group

Eric Richman
Pacific Northwest National Laboratory-DOE

Kurt Roberts
DuPont Electronic Technologies

Gary Rosenfield
JuiceWorks

Jana Rostron
Philips Hadco

Jashojit Roy
New Streetlights

Claudia Sainsot
Illinois Commerce Commission

Linda Sandahl
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Marci Sanders
D&R International, Ltd.

Sanwal Sarraf
Brite Lite

Greg Scala
Diogen Lighting, Inc.

Jerry Scarborough
GSSI / LED-Greenlighting

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Adesso, Inc.

Paul Scheidt
Cree

Karl Schroeder
Schroeder Industries

Thomas Schuller
H.E. Williams

Nora Schultz
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Ryan Schultz
3M

Tony Scianna
PolyBrite International, Inc.

Kevin Shelow
ACT, Inc.

David Shiller
MaxLite

Irene Signorino
Microsemi Corporation

Brian Simmons
Fluid Market Strategies

Ellen Sizemore
Osram Sylvania

Michael Smith
GE

Dave Smolinski
Georgia Power Company

Bill Solfisburg
Fawoo Tech North America, LLC.

David Spartano
EHI

Dan Sperling
Akoya

Mike Stanch
360 Energy Group/SEDAC

Ron Steen
Xicato

Lauren Stoller
Lazard Capital Markets

Pete Strasser
International Dark-Sky Association

James Sun
Dew & Ken Optoelectronics (Zhengzhou), Inc.

Eli Szamosi
OnSpeX

Laura Tang
Toyota Tsusho America, Inc.

Ruth Taylor
Pacific Northwest National Laboratory

Michael Thornton
Focal Point LLC

Paul Thurk
ARCH Venture Partners

Marsha Turner
International Association of Lighting Designers

Vickie Towe
Micron

Jacquelyn Tran
Southern California Edison

Jason Tuenge
Pacific Northwest National Laboratory

RicoTurisno
Digital Light

Alberto Uggetti
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Anand Upadhyay
Philips

Guy Vaccaro

Nguyen Violette
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Jason Vogel
Absogreen

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Madonna Wallace
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Terrence Walsh
TempoIndustries, Inc.

Chris Walsh
Juno Lighting Group

John Walter
National Grid

Karen Warnke
Ameren Illinois Utilities

Dan Weinheimer
City Manager's Office, City of San Marcos

Bill Weiss
Power Integrations

Scott Wells
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Fred Welsh
Radcliffe Advisors, Inc.

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Jason West
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Chip Westenberger
Arrow Electronics

Richard Westlake
Abundance Technologies

Liesel Whitney-Schulte
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PolyBrite International, Inc.

Karmen Wilhem
Alliant Energy

Ralph Williams
Walmart

Kevin Willmorth
Lumenique LLC / Architectural SSL Magazine

A Winton
Radionic

Howard Wolfman
Lumispec Consulting

Ken Woolcutt
Ameren Illinois Utilities

Jay Wrobel
Midwest Energy Efficiency Alliance

Walter Wu
Pixon Technologies

Cheryl Wynn
Southern California Edison

Frank Wysaski
Light Emitting Designs

Zhiling Xu
SoundOff Signal

Hiroshi Yagi
IMAnet, Inc.

Patrick Yang
Sunten Technology USA

Kevin Youngquist
Earthtronics

Lei Yu
ITI Group, USA

William Yu
ITI Group, USA

Volkan Yuksel
North Star Lighting

Vic Zaderej
Molex

Scott Zimmerman
Golden Eye